PROTECTING
WATER QUALITY

A field guide to erosion, sediment and stormwater best management practices for development sites in Missouri and Kansas.

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Shockey Consulting Services

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PREFACE

Purpose

The purpose of this field guide is to provide developers, contractors, site managers and inspectors with a guide to the installation and maintenance of construction site erosion, sediment and stormwater control practices in Kansas and Missouri. Proper installation and maintenance of these structural and biological practices will protect our valuable water resources from harmful pollutants.

This guide can also be a useful reference document for engineers, planners, public officials and others involved in land disturbance activities, although it is not intended as a design manual. For detailed design guidance, please refer to the numerous references and manuals listed in Appendix C and Appendix D. For further reference, see *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011*. This guide also provides a summary of state-of-the-practice stormwater control measures for long-term runoff management.

Disclaimer

This guide is not intended to be a manual for designing plans and specifications, but a source of information about erosion, sediment and stormwater control best management practices. The contents should not be interpreted as necessarily representing the policies or recommendations of other referenced agencies or organizations. Refer to state, federal and local regulations and permits for applicable design criteria. Permission has been granted for all copyrighted photos and schetches as applicable.

This is not a complete list of urban-applicable practices. For more complete information, refer to references cited throughout this guide in Appendix C and Appendix D). You may also contact your nearest Missouri Department of Natural Resources' Regional Office at www.dnr.mo.gov/regions/regions.htm or visit the Department's stormwater clearinghouse at www.dnr.mo.gov/env/wpp/stormwater.

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The second edition of the guide was a cooperative project of the Mid America Association of Conservation Districts', their Board of Supervisors in Kansas City, Missouri, the USDA's Natural Resources Construction Service, or NRCS – Kansas and Missouri, the Mid America Regional Council, or MARC, of Kansas City, Missouri and many of those involved in the original publication.
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The Missouri Department of Natural Resources would like to thank the following individuals for their valuable contributions to this project. The quality of this guide has been greatly enhanced by their advice, suggested changes, additions and overall assistance.

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North Carolina Erosion and Sediment Control Field Manual, 1991.

CHAPTER 1

PURPOSE AND SCOPE OF THIS GUIDE

Stormwater management is essential to ensuring a clean urban environment, but is just as important to building a vital community. Achieving both of these goals require a coordinated strategy. This guide provides developers, contractors, planners, local government officials and the general public information to assist them with harmonizing these community efforts.

This guide begins with a discussion on the causes and effects of stormwater impacts on community life. Persons involved with managing stormwater should understand the basics of water movement and its capacity to transmit harmful pollutants and cause physical damage. After introducing these fundamentals, the guide presents the many different options and techniques for controlling stormwater. The guide is designed to help the reader obtain the knowledge necessary to develop an effective and cost efficient strategy to manage stormwater within their unique community.

The Importance of Community Stormwater Management

High density human activities, particularly urbanization without proper design can alter water drainage patterns and add pollutants to our rivers, lakes and streams. Recent studies by the U.S. Environmental Protection Agency, or EPA, state water pollution control agencies and universities show stormwater runoff as a major source of urban water pollution. Polluted water runoff endangers humans by polluting the water sources being used for drinking, household purposes, recreation and fishing.

Soil sediment leaving the site of construction activity is a large contributor to water pollution. This sediment not only carries soil particles (the major pollutant), but can also carry attached pollutants such as petroleum products, metals, chemicals, pesticides, organic products and bacteria.

Sediment loading rates from construction sites are typically 10 to 20 times greater than pre-construction rates (North Carolina DEHNR, 1993). Over a short period of time, construction sites can contribute more sediment to receiving streams than was previously deposited over several decades.

There are three main reasons why construction activities increase pollutant loads in runoff. First, the volume and rate of runoff are typically increased, providing a larger capacity to transport pollutants to rivers and lakes. This is why it is critical that best site designs and post-construction practices are well understood and considered before the project is even designed and constructed. See *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011*. Second, the vegetation is removed leaving bare soil that is much more vulnerable to erosion, resulting in sediment moving into receiving waters. The third reason is some pollutants (e.g., petroleum products, chemicals from construction materials, metals, debris), are added to the site

during construction (*After the Storm*, EPA Fact Sheet 833-B-03-002, January 2003). These pollutants can attach to the soil particles or remain suspended in the stormwater runoff and move directly off-site to the stream.

The Evolution of Best Management Practices

The industry of erosion and sediment control is very young especially when looking at urban and construction activity controls. Urban erosion and sediment control has been regulated since the early 1970s, and in most places, since the 1990. In the beginning, the four most often used devices were the straw bale, rock construction exit, sediment basin and silt fence. Straw bales are no longer recognized by EPA, and many local ordinances do not allow their use. This guide will cover straw bale use for very small areas of sheet flow only. The rock construction exit will be covered but has been found to have little effect for reducing track out, and it requires very high maintenance.

This guide will look at alternatives and controls to add to the rock exit to make it more effective. Significantly different is the added emphasis to erosion control as the first step in reducing sediment runoff. The sediment (silt) fence will still be covered but should be limited to small areas of overland sheet flow. There are many alternatives to sediment fence that are more effective, are easier to install and maintain and that limit the amount of ponding behind them.

This guide will likely not be updated as fast as new and improved devices are added to this industry. The thing to remember is to explore new and different control devices to find the ones that work best for the situation at the site. It is important to change out devices found to be less effective at controlling the discharge of sediment and other pollutants from the construction site.

This guide also will cover the Stormwater Pollution Prevention Plan, or SWPPP, which will explain the use of different devices and control measures that are a moving target during the construction project. The plan to control pollutants in stormwater runoff from the construction site is ever evolving and changing as the site conditions change. Changing and moving the control devices to fit the conditions of the site is a requirement of your land disturbance permit.

This guide will provide developers, contractors, planners, local government officials and the general public with the latest information on erosion. Sediment and stormwater control practices. Using practices that are state-of-the practice will achieve the greatest balance between providing environmental protection and achieving development goals at construction sites.

Development plans and designs that integrate well with the surrounding environment and embrace the existing community infrastructure will more often avoid the delays and cost associated with having to reevaluate and reconstruct these practices at a later date. Consequently, the installation of proper practices within the context of the environmental site design will support community growth, while “dated” practices may become a hindrance.

Current Legislation

As a result of evolving knowledge and skill for controlling stormwater, there will continue to be a changing mix of regulatory requirements in obtaining the necessary environmental permits. Success in implementing a community stormwater management program requires certain permitting processes be understood and integrated into the overall planning efforts. Erosion, sedimentation and stormwater runoff control is governed by federal, state and

local regulations. State permit coverage is required for all land-disturbing construction activities that disturb one or more acres over the life of the project or that are part of a larger common plan of development or sale that will disturb one or more acres over the life of the project. This includes projects less than one acre that are part of a larger common plan of development or sale. In addition to federal and state regulations governing land disturbance activities, more than 150 municipalities in Missouri are also required to regulate construction activities. Also, some non-regulated municipalities choose to enforce erosion and sediment control. In many cases, it may be necessary to obtain a permit from both the state and the municipality. The statutes currently in force are:

Federal

The federal Clean Water Act of 1972 and additions in 1987 established certain water pollution control regulations and permit requirements. Section 402 within the Clean Water Act titled National Pollutant Discharge Elimination System, or NPDES, provides for permit coverage to be obtained for the discharge of stormwater by industrial activities. In 1992, the NPDES program was modified to include land disturbance through construction as an industrial activity to regulate the discharge of sediments and other pollutants during construction. EPA administers the NPDES permit program but authorization can be granted to the state level (most states have permitting authority.) The Missouri Department of Natural Resources has delegated authority to regulate the NPDES permit program in Missouri and the Kansas Department of Health and Environment, or KDHE, has delegated authority to regulate the NPDES permit program in Kansas. EPA typically acts more as an auditor for the state programs, but retains the authority to directly enforce the regulations of construction sites.

The U.S. Army Corps of Engineers governs the placing of dredge or fill material in waterbodies and development or removal of wetland areas. This falls under Section 404 of the Clean Water Act. Other Clean Water Act permits are available on the Missouri Department of Natural Resources' website at www.dnr.mo.gov/env/wpp/stormwater/sw-other-site-permits.htm which includes the following information.

General Information

Missouri Department of Natural Resources

- Dam Safety Permits (www.dnr.mo.gov/env/wrc/damsft/pubs_av.htm#forms) from the Department's Water Resources Center may be required for dam construction activities, especially if the dam is 35 feet or greater in height or the water is listed on Missouri's Impaired Waters List (www.dnr.mo.gov/env/wpp/waterquality/303d/index.html). Contact the Water Resources Center prior to building a dam. See general Dam and Reservoir Safety Program information at www.dnr.mo.gov/env/wrc/damsft/damsfthp.htm.

- Sand and Gravel Mining Permits (www.dnr.mo.gov/env/lrp/homesg.htm) may be required from the Department for commercial removal of in-stream sand and gravel. Contact the Department's Land Reclamation Program for permit applications and instructions. Call 573-751-4041 or 800-361-4827 and ask for the Industrial Minerals Unit.

- 401 Certification (www.dnr.mo.gov/env/wpp/401/index.html) from the state department per Section 401 of the Clean Water Act is required when placing material, or fill, into the jurisdictional waters of the U.S. Examples are culverts under road crossings, riprap along stream banks and stormwater outfall pipes. The term jurisdictional waters here refer to large lakes, rivers, streams and wetlands, including those that don't always contain water. The permitting and certification process is shared between the Department, under Section 401, and the U.S. Army Corps of Engineers, under Section 404.

U.S. Army Corps of Engineers

- A 404 permit (http://apps.ecy.wa.gov/permithandbook/permitdetail.asp?id=37) from the Corps is required per Section 404 of the Clean Water Act for the discharge of dredged or fill material in all waters of the United States, including rivers, streams, lakes and wetlands. This includes work such as site development fills, causeways or road fills, dams and dikes, artificial islands, bank stabilization (riprap, seawalls and breakwaters) levees, landfills, fish attractors, mechanized clearing of wetlands and certain types of excavation activities, etc.
- Map of Missouri's five Corps districts and their program service areas (www.dnr.mo.gov/env/wpp/401/corps-map3.gif).
- Kansas City District map of counties and general program information (www.nwk.usace.army.mil/regulatory/boundary.htm).
- Rock Island District Mississippi Valley Division (Northeast corner of Missouri) (www.mvr.usace.army.mil/).
- Memphis District Mississippi Valley Division (Southeast bootheel corner of Missouri) (www.mvm.usace.army.mil/).
- St. Louis District list of counties (www.mvs.usace.army.mil/permits/permtcou.htm) and general program information (www.mvs.usace.army.mil/permits/TOCStL.htm).
- Little Rock District boundary map (Southern Missouri) (www.swl.usace.army.mil/regulatory/images/districtlettersize.pdf) and general program information (www.swl.usace.army.mil/regulatory/index.html).
- The Corps may also require a permit for any work or structures in, under or over any navigable Waters of the United States per Section 10 of the Rivers and Harbors Appropriations Act of 1899 (www.epa.gov/owow/wetlands/regs/sect10.html). This includes such items as boat docks, boat ramps, powerlines, excavation, filling, etc. This is more likely to be applicable in projects adjacent to the Lake of the Ozarks, the Osage River below Bagnell Dam and the Missouri, Mississippi and Gasconade rivers.

State

The Missouri Department of Natural Resources, the Kansas Department of Health and Environment and most other states regulate the quality of stormwater runoff by requiring permit coverage under the NPDES program - whenever there is land disturbance due to construction subject to regulations. In Missouri, the NPDES program is regulated through the Missouri Clean Water Law (10 CSR 20-6.200). The general land disturbance permit addresses the reduction or elimination of pollution in stormwater and certain non-stormwater discharges from:

- Construction sites that will disturb one acre or greater.
- Construction activities that are part of a larger common plan of development or sale that will disturb one acre or more over the life of the project.

Local Government

You may also need to obtain a permit or similar approval from the municipality where your construction project is located. Visit the Missouri Department of Natural Resources' Stormwater Clearinghouse website at www.dnr.mo.gov/env/wpp/stormwater/sw-phaseII-communities.pdf for a list of municipal separate storm sewer systems, or MS4s, required to implement a construction program. Note also that several unregulated MS4s choose to regulate erosion and sediment control.

Local Municipal Separate Storm Sewer System Programs

The NPDS permit program also requires certain entities that manage municipal separate storm sewer systems, or MS4s, to have a land disturbance ordinance and permit program. If your construction project falls within any of these local programs, you will also need to understand and abide by the local ordinance and permit program. You may also need to obtain permit coverage or similar approval for the municipality where your construction project is located. Visit the Missouri Department of Natural Resources' Stormwater Clearinghouse website at www.dnr.mo.gov/env/wpp/stormwater/sw-phaseII-communities.pdf for a list of municipal separate storm sewer systems required to implement a construction program.

Missouri's Phase I & Phase II Stormwater Communities *Revised March 29, 2010*

Arnold	Dardenne Prairie	Ladue	Riverview, Village of
Ballwin	Dellwood	Lake Lotawana	Rock Hill
Battlefield	Des Peres	Lake St. Louis	Rolla
Bellefontaine Neighbors	Duquesne	Lakeshire	Sedalia
Bel-Nor, Village Of	Ellisville	Lebanon	Shrewsbury
Bel-Ridge, Village Of	Excelsior Springs	Lee's Summit	Sikeston
Belton	Farmington	Liberty	Springfield*
Berkeley	Fenton	Manchester	St Charles
Black Jack	Ferguson	Marlborough, Village of	St. Ann
Blue Springs	Festus	Marshall	St. Charles County
Boone County	Florissant	Maryland Heights	St. George
Breckenridge Hills	Fort Leonard Wood	Maryville	St. John
Brentwood	Frontenac	Mexico	St. Joseph
Bridgeton	Fulton	MoDOT	St. Louis (MSD)
Buchanan County	Gladstone	Moberly	St. Louis County
Byrnes Mill	Glendale	Moline Acres	St. Martins
Callaway County	Grain Valley	Neosho	St. Peters
Calverton Park, Village of	Grandview	Newton County	Sugar Creek
Cape Girardeau	Green Park	Nixa	Sunset Hills
Carl Junction	Greene County	Normandy	Town And Country
Carterville	Greenwood	North Kansas City	U.S. Medical Center for Federal Prisoners
Carthage	Hanley Hills, Village of	Northwoods	
Cass County	Hannibal	Norwood Court, Town of	University of Missouri-Col
Charlack	Hazelwood	Oakland	Valley Park
Chesterfield	Herculaneum	O'Fallon	Vinita Park
Christian County	Holts Summit	Olivette	Warrensburg
Clarkson Valley	Independence*	Overland	Warson Woods
Clay County	Jackson, City of	Ozark	Washington
Claycomo, Village of	Jackson County (Salem E)	Pagedale	Weatherby Lake
Clayton	Jasper County	Parkville	Webb City
Cole County	Jefferson City	Pevely	Webster Groves
Columbia	Jefferson County	Platte County	Weldon Spring
Cool Valley	Jennings	Pleasant Valley	Wentzville
Cottleville	Joplin	Poplar Bluff	West Plains
Country Club, Village of	Kansas City*	Raymore	Wildwood
Crestwood	Kennett	Raytown	Winchester
Creve Coeur	Kirksville	Richmond Heights	Woodson Terrace
Crystal City	Kirkwood	Riverside	

*Three of these communities came in under Phase I. Communities may be added to or removed from this list after further review. This list is also subject to change upon completion of the 2010 U.S. Census.

Missouri Permit Requirements

Land Disturbance General Permit Requirements

Site owners or operators disturbing land due to construction activity within Missouri generally need to apply for permit coverage, to be issued under one of the following three general Missouri State Operating Permits. In some circumstances, the Missouri Department of Natural Resources may require you to submit an application for a site-specific permit. All general permits listed below are available on the department's website at www.dnr.mo.gov/env/wpp/stormwater/sw-land-disturb-permits.htm.

1. MO-R10A-Z - General construction or land disturbance activities.
2. MO-R100 - Construction or land disturbance activity performed by or under contract to a city, county or other governmental jurisdiction.
3. MO-R109 – Construction or land disturbance near valuable resource waters.

Valuable resource waters are stormwater discharges within 1,000 stream feet of:

- Streams identified as a losing stream.
- Reservoirs or lake used primarily as a public drinking water supply.
- Streams or lakes listed as an outstanding national or state resource waters, such as cold water trout streams.
- Streams, lakes or reservoirs identified as critical habitat for endangered species.
- Streams, lakes, or reservoirs listed as impaired for sediment or an unknown pollutant by standard Missouri Department of Natural Resources methodology.

Also included as valuable resource waters are stormwater discharges:

- Within 100 stream feet of a permanent stream (Class P) or major reservoir (Class L2).
- Within two stream miles upstream of biocriteria reference locations.
- Where any of the disturbed area is defined as a wetland (Class W), by 10 CSR 20-7.031(1)(F)7.
- The stormwater discharges to a sinkhole or other direct conduit to groundwater.

Other permits or authorizations may be necessary for your construction project. For more information visit www.dnr.mo.gov/env/wpp/stormwater/sw-other-site-permits.htm.

Permit Coverage Application Forms and Fees:

To obtain permit coverage from the State of Missouri for land disturbing activities visit www.dnr.mo.gov/env/wpp/stormwater/sw-land-disturb-permits.htm.

To obtain land disturbance permit coverage for construction projects complete, sign and submit *Form E - Application for General Permit*, Form--MO 780-0795 and *Form G - Application for Stormwater Permit Under the General Permit: Land Disturbance*, Form--MO 780-1408. If the land disturbing activity is between one and five acres, use *Form O - Application for Land Disturbance Less than 5 Acres*, Form--MO 780-1829 instead of Form G. These forms must be signed by persons according to the requirements in the regulations.

The permit coverage fee is $300 and must be included with the forms and submitted to your local Missouri Department of Natural Resources office.

Missouri Department of Natural Resources Central and Regional Offices

Central Office
PO Box 176
Jefferson City, MO 65102-0176
573-751-3443

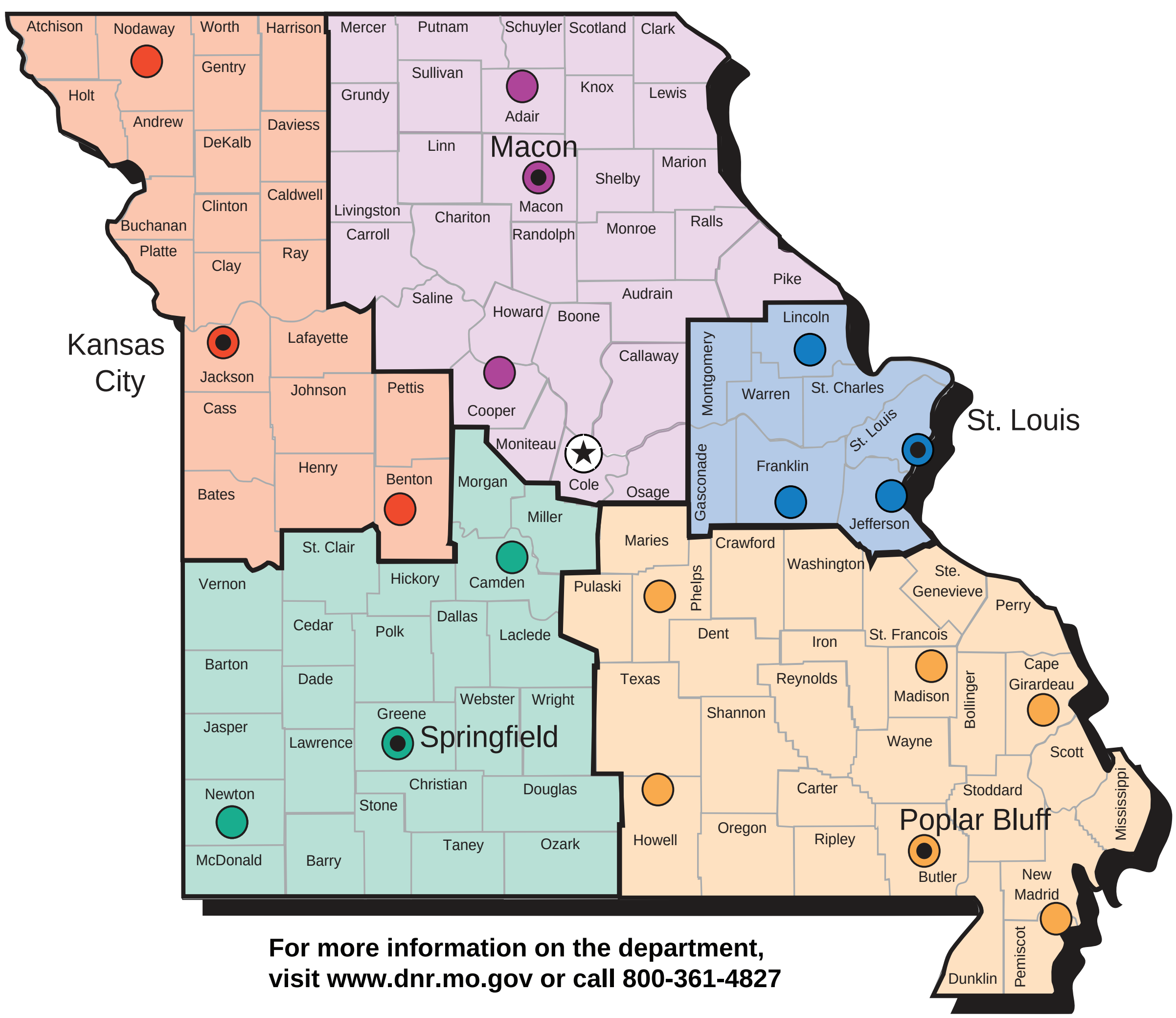
Kansas City Regional Office
500 NE Colburn Road
Lee's Summit, MO 64086-4710
816-622-7000

Northeast Regional Office
1709 Prospect Drive
Macon, MO 63552-2602
660-385-8000

Southeast Regional Office
2155 North Westwood Blvd.
Poplar Bluff, MO 63901
573-840-9750

St. Louis Regional Office
7545 S. Lindbergh, Suite 210
St. Louis, MO 63125
314-416-2960

Southwest Regional Office
2040 W. Woodland
Springfield, MO 65807-5912
417-891-4300



For more information on the department, visit www.dnr.mo.gov or call 800-361-4827

In addition to filling out and submitting these forms for permit coverage, a SWPPP must be prepared specific to the project for which permit coverage in needed. Guidance for preparation for this plan is available under the heading SWPPPs, in this handbook. A good source of information about SWPPP preparation is available on EPA's website at cfpub.epa.gov/npdes/stormwater/swppp.cfm.

The general permit also requires the permittee to perform regularly scheduled inspections of the SWPPP and all best management practices on the construction site to make sure they are functioning and maintained properly to reduce or eliminate sediment and other pollutants from leaving the construction site and entering a waterway. Additional information on inspections is available in the Inspection for Erosion, Sediment and Stormwater Control section of this handbook.

If the permittee sells less than one acre of a permitted site to an entity for commercial, industrial, or residential use (unless sold to an individual for the purpose of building his or her own private residence) that is part of a common plan or sale, this land remains a part of the common sale and regulated by this permit. Therefore, the permittee is still responsible for erosion control on the sold property until termination of the permit.

After the construction project or land disturbing activity is complete and the site is stabilized to meet the requirements within the regulations, permit coverage can be terminated. To do so complete, sign and submit Missouri Department of Natural Resources' *Form H - Request for Termination of a General Permit*, Form--MO 780-1409. A Missouri State Operating Permit expires within five years from its effective date. If the active construction project will not be completed by the permit expiration date, it will be necessary to re-apply for coverage within 180 days of permit expiration.

Kansas Permit Requirements

For information about requirements for Construction Activity permit coverage in Kansas visit their website at www.kdheks.gov/stormwater/index.html#construct or contact:

Kansas Department of Health and Environment
Bureau of Water
Building 283, Forbes Field
Topeka, KS 66620
913-296-5557

Training and Certification Information

The Missouri land disturbance permits require that persons designated for environmental responsibility and inspections have a thorough and demonstrable knowledge of the site's SWPPP and erosion and sediment control practices in general. Although currently there are no certification requirements in Missouri for specific education or background for those persons preparing the SWPPP or conducting the site inspections, it is in the permittees' best interest to ensure all permit requirements are being met. This includes proper SWPPP preparation and inspections of controls to ensure the site is in compliance at all times. There are numerous training and certification opportunities available in the field of erosion and sediment control and stormwater pollution prevention plan preparation.

The International Erosion Control Association provides educational opportunities through their annual conferences and live and online instruction programs. Nationwide certification programs are available through EnviroCert International, National Institute for Certification in Engineering Technologies and CISEC Inc. Additional information about these programs are available on the Missouri Department of Natural Resources website at www.dnr.mo.gov/env/wpp/stormwater/sw-land-disturb-permits.htm.

CHAPTER 2

CAUSES AND EFFECTS OF EROSION AND SEDIMENTATION, HYDROLOGIC CHANGES AND POLLUTION TRANSPORT

The major problem associated with erosion on a construction site is the movement of soil off the site and its consequent pollution of receiving rivers, streams and lakes. In Missouri, 70 to 90 percent of the eroded soil (sediment – see Glossary) that reaches any type of channel is transported to the state's water resources.

Types of Soil Erosion

Soil erosion is a natural process that wears away the earth's surface. Soil particles are detached (eroded), transported (as sediment) and deposited (sedimentation) by wind, water, ice or gravity. On a construction site, the erosion process is accelerated because the soil is left bare and unprotected by vegetation. Water and wind erosion will be described in detail below.

Water Erosion

There are five types of water erosion (shown in Figure 2.1) described below and ranked from least severe to most severe. Splash and sheet erosion can best be prevented by protecting the land surface with vegetation, mulch or erosion control blankets. Sheet, rill and gully erosion can be controlled by keeping runoff velocities slow.

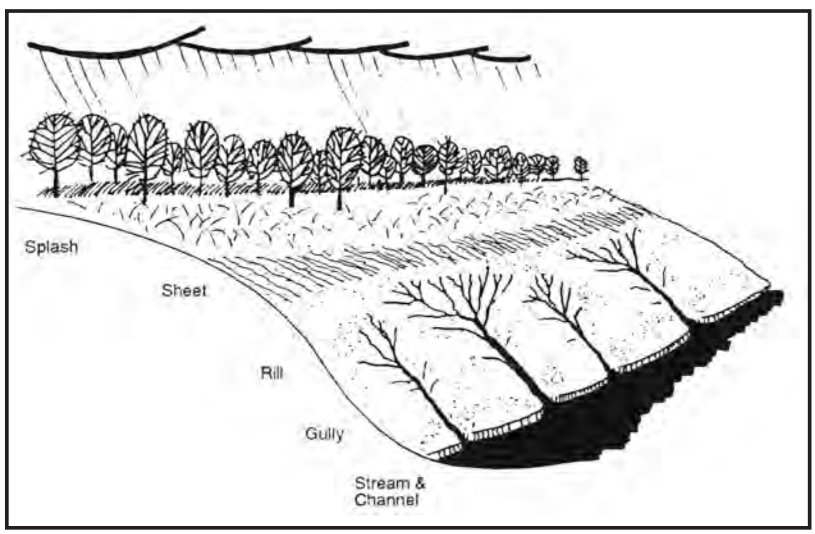


Figure 2.1 The Five Types of Soil Erosion on an Exposed Slope Source: North Carolina DEHNR, 1993

Splash: Splash erosion results from the direct impact of falling drops of rain on soil particles. This impact breaks the bonds between the particles, dislodges them and splashes them into the air. The dislodged soil particles can then be easily transported by the flow of surface water runoff.

Sheet: Sheet erosion is the removal of a thin layer of exposed surface soil by the action of raindrop splash and runoff. The water moves in broad sheets over the land, picks up these particles and carries them along as it flows downhill.

Rill: As the runoff moves down a slope, it cuts small paths or rills. In rill erosion, water flowing through these paths detaches more soil from their sides and bottoms.

Gully: Further down the slope, water tends to concentrate in channels and pick up speed. In gully erosion, soil is removed rapidly by water gushing over the headcut or uphill end of the gully, by concentrated flow scouring the sides and bottom of the gully and by water removing soils that have slumped from the sidewalls of the gully. A nearly vertical headcut allows water falling over the surface to undermine the bank so the gully moves upslope. Large earthmoving equipment is required to reshape or control gullies.

Stream and Channel: Increases in the volume, velocity and time of runoff may cause erosion of the receiving stream or channel banks and bottom.

Wind Erosion

Wind erosion is a serious environmental problem. Suspension, saltation and surface creep are the three types of soil movement that occur during wind erosion (See Figure 2.2).

Suspension: Occurs when very fine dirt and dust particles are lifted into the wind. The particles can be thrown into the air through impact with other particles or by the wind itself. Once in the atmosphere, these particles can be carried very high and be transported over extremely long distances.

Saltation: Fine particles are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they go. They travel approximately four times longer in distance than in height and when they strike the surface again they either rebound back into the air or knock other particles into the air. This is the major form of soil movement due to wind.

Creep: The large particles that are too heavy to be lifted into the air are moved through a process called surface creep. The particles are rolled across the surface after coming in contact with the soil particles in saltation.

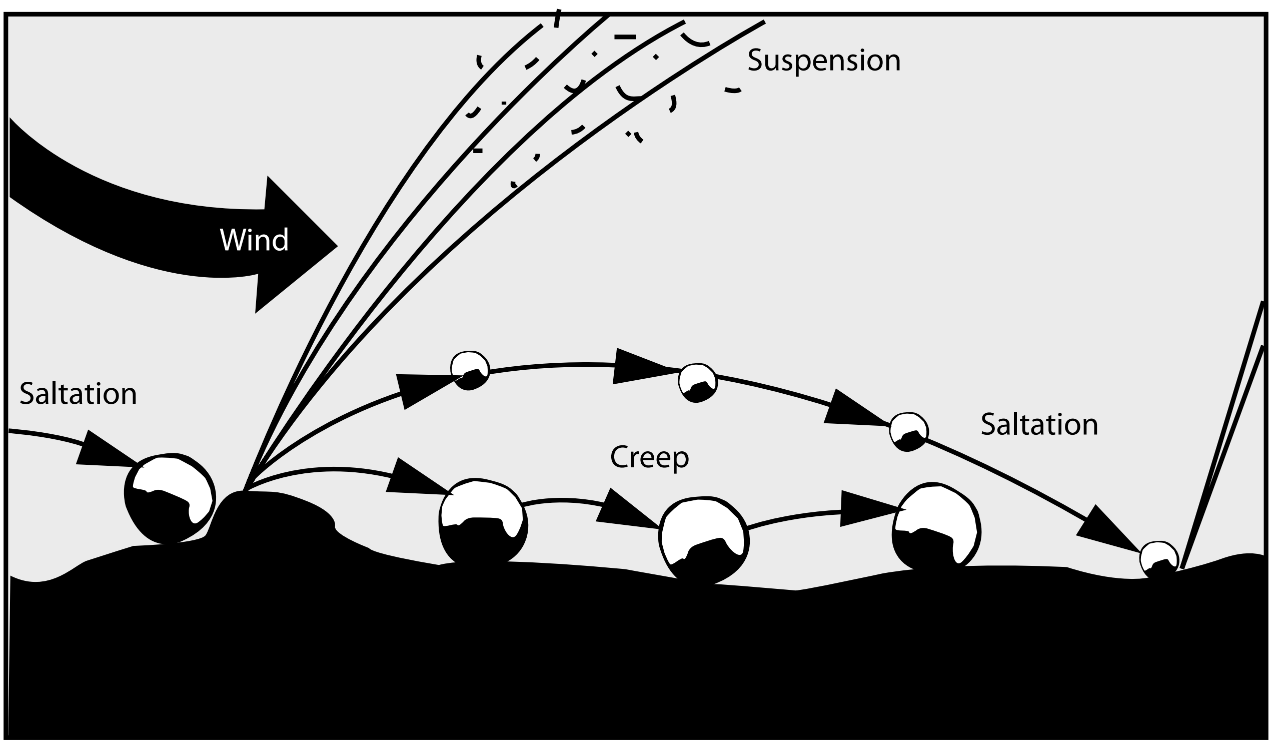


Figure 2.2 Types of Wind Erosion   Source: Wind Erosion Research Unit

Factors That Influence Water and Wind Erosion

The potential for a land area to erode is determined by several key factors: climate, rainfall, soil erodibility and the length and steepness of the slope. These factors are interrelated in their effect on the potential for erosion. The variability in terrain and soils makes erosion control unique to each development site.

A site specific soils analysis and the assistance of a registered design professional (see Glossary) can aid in the development of an effective erosion, sediment and stormwater control plan.

Basic Principles of Erosion Control

Keeping soil in place when possible is the first step to erosion control. If the soil must be exposed to stormwater and wind, then it must be contained on the construction site through sediment control measures. Remember erosion controls are preventative and sediment controls are corrective.

The contractor can control erosion and sedimentation most effectively by leaving vegetation intact as long as possible, avoiding removal of streamside vegetation, leaving wetlands in place and phasing in land disturbance to minimize the amount of soil exposed at any one time. Secondly, they can protect whatever soil is exposed from the erosive force of rain, surface water runoff and, in some cases, wind. Eroded soil must be captured and retained on the construction site. In addition, it is important to keep stormwater runoff at low velocities and volumes on-site, and at or below pre-development levels going off-site. Ideally, no sediment is to leave the perimeter of the site. Reasonably, of course, some minimal amount of sediment may leave the site. The following principles will help minimize erosion on the construction site, significantly reduce soil from leaving the site and limit off-site sedimentation that result in water pollution.

Erosion from the splash of a raindrop is caused from the energy of the drop falling from the sky with a specific size and velocity. The most important part of erosion control is to design to protect the soil from the energy of the raindrop by reducing the area of bare soil at any time. Keep as much of the existing vegetation in place as possible. For those areas that were stripped of the existing, protective vegetation, cover the bare soil with erosion control measures and reestablish permanent vegetation as quickly as possible. Remember erosion controls are preventative and sediment controls are remediation.

Retain Existing Vegetation Wherever Feasible

Vegetation is the most effective form of erosion control. Try to integrate the existing vegetation including grass, trees and shrubs into the design to reduce the amount of land disturbance. For those areas where the vegetation must be removed, re-establish vegetative cover as soon as possible to reduce the potential for erosion in these areas. Retain all existing riparian corridor to waterways unless removal is absolutely necessary.

Design the Development to the Site

Reduce the amount of soil cut and fill that could occur over the site. One of the best ways to minimize the risk of erosion and sedimentation problems by construction is to disturb as little of the land as possible. The better the development fits with the topography of the site, the less the grading activity occurs, thereby minimizing the amount and intensity of land disturbance. When development is tailored to the natural topography of the land, less massive earth movement is necessary and erosion potential is greatly reduced. It is also important to avoid disturbance of sensitive areas. You should try to avoid disturbance near wetlands and within the riparian (see Glossary) corridor of perennial streams.

Reduce Surface Runoff by Increasing Infiltration

Vegetation is the most effective form of erosion control. It provides both erosion control and stormwater runoff reduction through infiltration. You can design for increased infiltration by altering the soil texture and subsoil for greater void spaces, which will increase infiltration. Try to integrate the existing vegetation including grass, trees and shrubs into the design to reduce the amount of land disturbance. Retain all existing riparian corridor to waterways unless removal is absolutely necessary. The plants dissipate the energy of the raindrop, reducing the potential for erosion and the root systems increase infiltration and decrease surface runoff.

Protect the Land Surface

Schedule and limit grading activities to minimize bare soil areas and the time of exposure. Consider the use of erosion control blankets, mulch or other erosion control measures when appropriate. Use diversions and perimeter protection to intercept runoff and divert it away from bare soil slopes. Install these practices before clearing and grading or as soon as possible. Stabilize the construction entrance and channels immediately. Establish vegetation on graded areas as quickly as possible or whenever work is interrupted. As stated in the *Missouri State Operating General Permit for Land Disturbance*, “Where soil disturbing activities cease in an area for 14 days or more, the permittee shall construct BMPs to establish interim stabilization.”

Keep Runoff Velocities Low

Preserve natural vegetation where possible; mulch and vegetate exposed areas immediately after grading to allow infiltration and slow surface runoff. Use practices that shorten or “break” the slopes to reduce flow volumes and velocities, such as terraces or wattles. Convey stormwater runoff away from steep slopes to stable outlets and detain water in holding ponds before leaving the site.

Capture Sediment on the Site

Sediment traps, basins and barriers are designed to reduce runoff velocity, not filter it; allowing the water to pool and the sediment to settle out. Several sediment traps or barriers located at the border of a graded area are more effective than a single large sediment basin near the site boundary. These practices also reduce the volume and velocity of stormwater runoff.

Schedule Land Grading

The contractor can control erosion and sedimentation most effectively by coordinating the grading sequence and the installation of erosion and sediment control practices. Install key sediment control practices before site grading begins. Schedule or limit grading to small areas. Install the permanent stormwater drains early in the construction and protect all inlets from sedimentation.

Design, Install. Operate and Maintain Practices Properly

Proper design, installation, operation, inspection and maintenance are vital to the success of erosion and sediment control practices. These elements will be covered in Chapter 5. Choosing the wrong practice, improper installation, improper operation and lack of maintenance are the cause of most failures. Failures of installed practices can deliver large amounts of polluted water runoff into streams and lakes. A large structure that fails, such as a detention basin, may be hazardous or damaging to people and property; just as low points in a dike can cause major gullies to form on a fill slope. Ensure the appropriate practice is selected. Also, assign an individual to be responsible for routine checks, operation oversight, repairs and maintenance of erosion, sediment and stormwater control practices.

Figure 2.3 The improperly installed check dam created significant bank erosion. Source: *ABC's of BMP's LLC*

Hydrologic Changes

Land development in urban areas causes drastic changes in the local and watershed hydrology. As land is covered with roads, buildings and parking lots, the amount of rainfall that can infiltrate into the soil is reduced. Figure 2.4 shows the reduction in rainfall infiltration into the soil as paved surface and building cover increases. Table 1.1 shows a range of runoff coefficients for different land uses. The runoff coefficient, or "C" value in the Rational Method of determining runoff, is the percentage of rainfall runoff in the watershed.

This is one reason why construction practices must work hand-in-hand with post-construction runoff controls. It is a relationship that must be well understood. Post-construction controls are designed for the long-term additional runoff from the developed areas to reduce stormwater quantity while improving stormwater quality (See *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management*).

The first line of defense in protecting urban water quality is to assess the entire development site for water quality protection opportunities before ever designing where roads and structures are to be located. The initial stage of site design should work to preserve and enhance the existing features.

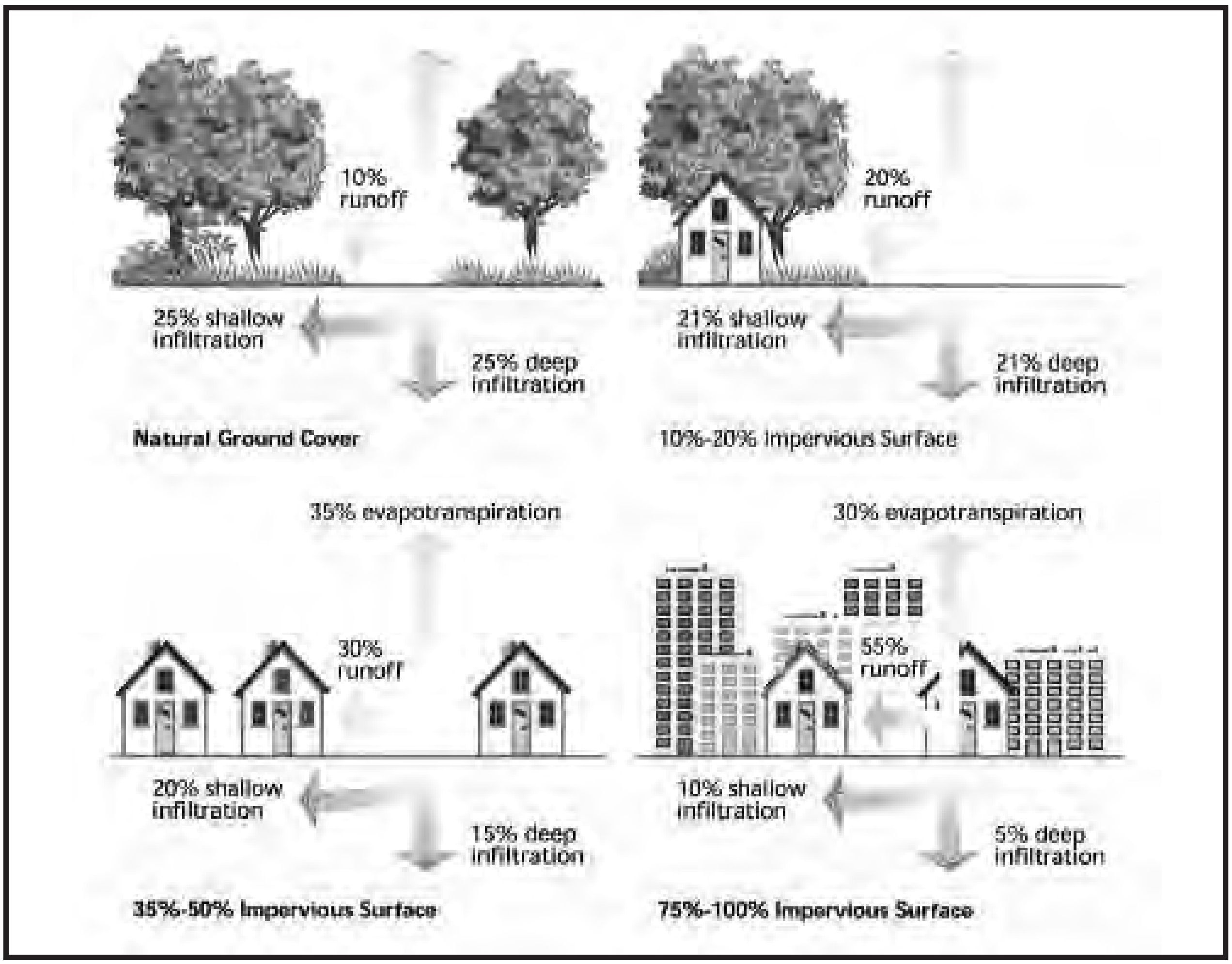


Figure 2.4 Typical changes in runoff flows resulting from paved surfaces
Source: USDA, NRCS, Stream Corridor Restoration, 2001

Land Use	Runoff Coefficient	Land Use	Runoff Coefficient
Business		Lawns	
Downtown	0.70 – 0.90	Sandy soil	0.05 – 0.20
Neighborhood	0.50 – 0.70	Heavy soils	0.13 – 0.35
Residential		Agricultural Lands	
Single Family	0.30 – 0.50	Bare packed soils	0.30 – 0.50
Multiunits, detached	0.40 – 0.60	Cultivated rows	0.30 – 0.60
Multiunits, attached	0.60 – 0.75	Pasture	
Residential, suburban	0.25 – 0.40	Heavy soils	0.15 – 0.45
Apartment	0.50 – 0.70	Sandy soils	0.10 – 0.25
Industrial		Barren slopes	
Light	0.50 – 0.80	Smooth, impervious	0.70 – 0.90
Heavy	0.60 – 0.90	Rough	0.50 – 0.70
Parks, cemeteries	0.10 – 0.25	Woodlands	0.05 – 0.25
Playgrounds	0.20 – 0.35		
Railroad yard	0.20 – 0.40		
Unimproved	0.10 – 0.30		

Table 1.1 Typical Runoff Coefficients as Percentages Source: *Goldman, Erosion and Sediment Control Handbook*, 1986

As land areas are developed, natural drainage patterns are modified when runoff is channeled into road gutters, storm sewers and paved surfaces. These changes concentrate the volume of runoff in drainageways and increase the speed of flow. This results in higher peak discharges and shorter times to reach peak discharge. Figure 2.5 shows typical pre-development and post-development discharge rates versus elapsed time for a site being developed for urban land use. The area under the curves represents the volume discharged. The increased volume and discharge rate shows how the discharge from the site is increased. The rapid rise and fall of runoff is often presented as dangerous flash flood events. Major flooding or soil erosion problems also occur often after an area has been developed.

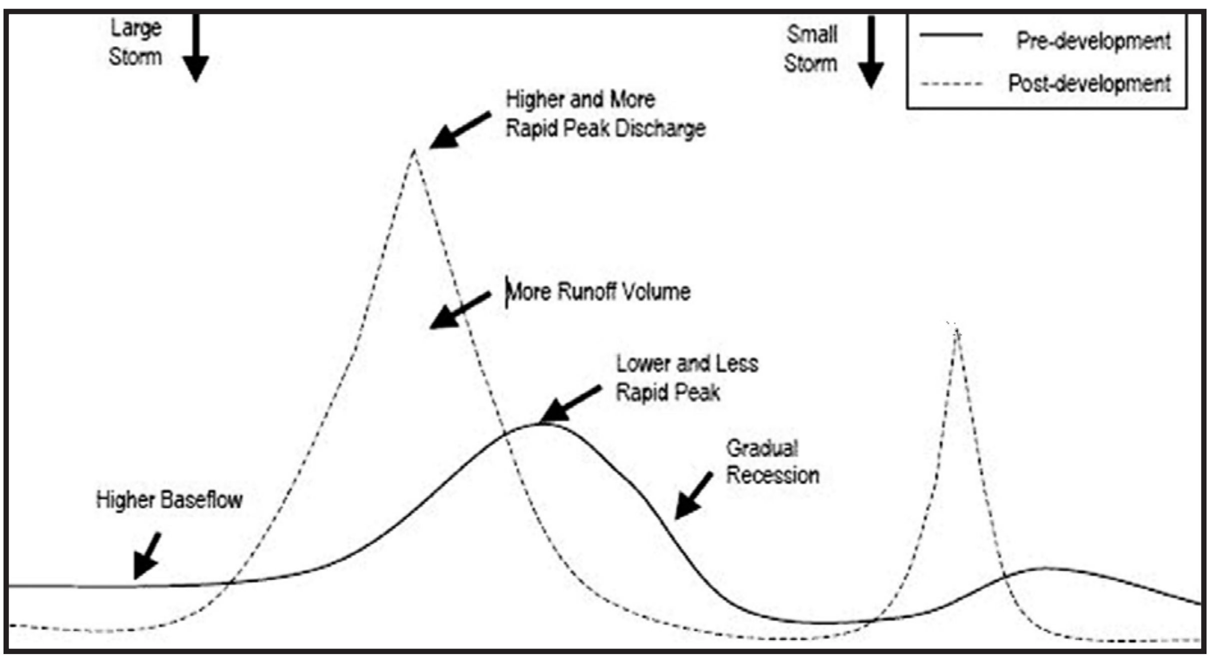


Figure 2.5 Consequences of Development to Urban Streams Source: EPA 841-B-05-004, November, 2005

Another hydrologic effect of urbanization is reduced stream flow during periods of low rainfall. This occurs because paved surfaces do not allow infiltration or retain the water in the soil that would naturally feed the streams. The result is deterioration of the aquatic ecosystem because of high pollutant loadings and low flow during periods of low rainfall.

During periods of high rainfall, the increased discharge rate and downstream flow often cause channel and streambank erosion in the receiving stream. Due to development and increase in impervious surfaces, there is less infiltration of surface water to groundwater and therefore more water arriving in stream channels and at a faster rate. This results in destabilization of streambanks and scouring of stream channels.

Removal of vegetation prior to construction activity is a major contributor to sediment moving off-site and entering nearby streams and lakes. Bare soil is highly vulnerable to erosion. Sediment movement from construction sites can range up to 35-45 tons/acre/year (ASCE and WFF, 1992). Vegetative cover is the most effective control of erosion and sediment loadings.

Pollution Transport

Water pollutants that are commonly transported by stormwater from construction sites in urban settings include sediments, nutrients, petroleum products, chemicals, metals, pesticides, fertilizers and other potentially toxic chemicals (*After the Storm*, EPA Fact Sheet 833-B-03-002, January 2003).

Sediment

Sediment, often incorrectly referred to as silt, (see Appendix A) from soil erosion is made up of soil particles and gravel washed into rivers, lakes and streams. It is the major pollutant in surface waters. Excessive sediment in waterbodies impairs aquatic ecosystems, reduces public water storage and increases drinking water treatment costs. These sediment particles are also a vehicle to transport other pollutants including nutrients, metals, petroleum products and bacteria to surface waters.

Runoff from construction sites is the major source of sediment in urban areas under development. Typical sediment loading rates from construction sites vary from 100 to 200 tons/acre/year (North Carolina DEHNR, 1993). Another major source of sediment is off-site streambank erosion, which is increased by the higher peak runoff flow rates and volumes previously discussed.

Nutrients

Phosphorus and nitrogen are the primary forms of nutrients that can cause water pollution. Lawn fertilizers used to establish and maintain vegetation can be significant sources of phosphorus. Nitrogen comes from fertilizer, too, but is also found in animal wastes, grass clippings and effluent from leaking septic systems.

Phosphorus and nitrogen are sources of food for the algae and bacteria that live in lakes, streams and rivers. Waters polluted with these nutrients develop large numbers of algae and bacteria that use up oxygen, causing fish and other beneficial organisms to die. Nitrates in drinking water are responsible for the “blue baby syndrome” that has caused illness and deaths in infants and have been linked to certain forms of cancer in adults (*Health and Environment Digest*, 1988).

Nutrient pollution can be prevented by composting grass clippings and animal wastes, and repairing leaking septic systems. Nutrient pollution from construction sites can be minimized by applying fertilizer at the rate recommended by a soil test.

Petroleum Products

Petroleum products float on water and are visible. The hydrocarbons in petroleum have a strong characteristic for attaching to sediment particles. Hydrocarbons are known to be toxic to aquatic organisms. Common sources of petroleum products at the construction site are oil storage, fuel facilities, leaks from crankcases and improper disposal of drain oil.

Chemicals

Paints, solvents, sealants, cleaning agents and caulks may be found on construction sites. These chemicals along with chemically composed or treated construction materials may enter the runoff water. Water quality is degraded and removal during water treatment processes may be very expensive.

Metals

Trace metals including lead, zinc, copper, chromium, cadmium and nickel are found on construction sites. In high concentration these metals are toxic to aquatic life. They originate from building materials, vehicle emissions and road sand or salt. Studies have shown that trace metals bioaccumulate in plants and aquatic life in areas where they are contained in sediment.

CHAPTER 3
INTERPRETING STORMWATER FEATURES IN THE SITE DEVELOPMENT PLAN

Before beginning preparation of the Stormwater Pollution Prevention Plan, the preparer needs to carefully review the site development plan, or SDP, opportunities to prevent and control stormwater pollution. The scope of stormwater controls outlined in the plan may range from minimal representation to full scale environmental site design. See Diagram 3.1 Regardless of the scope of features presented, the site development plan should be carefully examined by the preparer for ways to optimize stormwater control. The preparer's approach to selecting and installing stormwater control measures can significantly impact benefits from their use and can lead to cost savings.

Site Development Plan

Contemporary SDP with Environmental Site Design showing elevations and multiple stormwater practices.

- Elevations.
- Rain gardens, bioswales.
- Vegetated street edges/parking lots.
- Stream setback buffered with vegetation.

Contemporary SDP with Environmental Site Design showing elevations and multiple stormwater practices.

- Elevations.
- Stormwater basin.

Diagram 3.1

Site development plans that contain a well constructed environmental site design should be easy to interpret. For example, Figure 3.1 demonstrates opportunities available to the Stormwater Pollution Prevention Plan preparer and contractor for enhancing stormwater control. In this example, there is no basin for permanent stormwater runoff control. Therefore, it would be less practical to build a large costly sediment basin, because it would need to be back-filled upon project completion, instead of being converted to a permanent stormwater pond. In this project, the prairie provides for sheet flow of larger storms that ultimately flow into woods along the perimeter. The woods along the southwest part of the property provide further protection of the

natural drainage areas and the stream below   Also, rain gardens and bioswales are designed into the plan to capture runoff at its source, because these practices will slow runoff and filter pollutants after the development is complete. The Stormwater Pollution Prevention Plan should explain how these permanent stormwater control features will be protected during the property development. The Stormwater Pollution Prevention Plan, is discussed in more detail in Chapter 4.

The depressions for rain gardens and bioswales can be made ahead of time to catch sediment during construction, or they can be fenced off for protection during construction. If used to catch sediment, they will need to be cleaned out and converted to permanent use when the development is finished and the site is stabilized. In either case, these sites and any connecting flow paths should be protected from traffic compaction, material storage and contaminated runoff, and such protection measures should be identified in the Stormwater Pollution Prevention Plan. Fencing these protection zones will provide added protection.

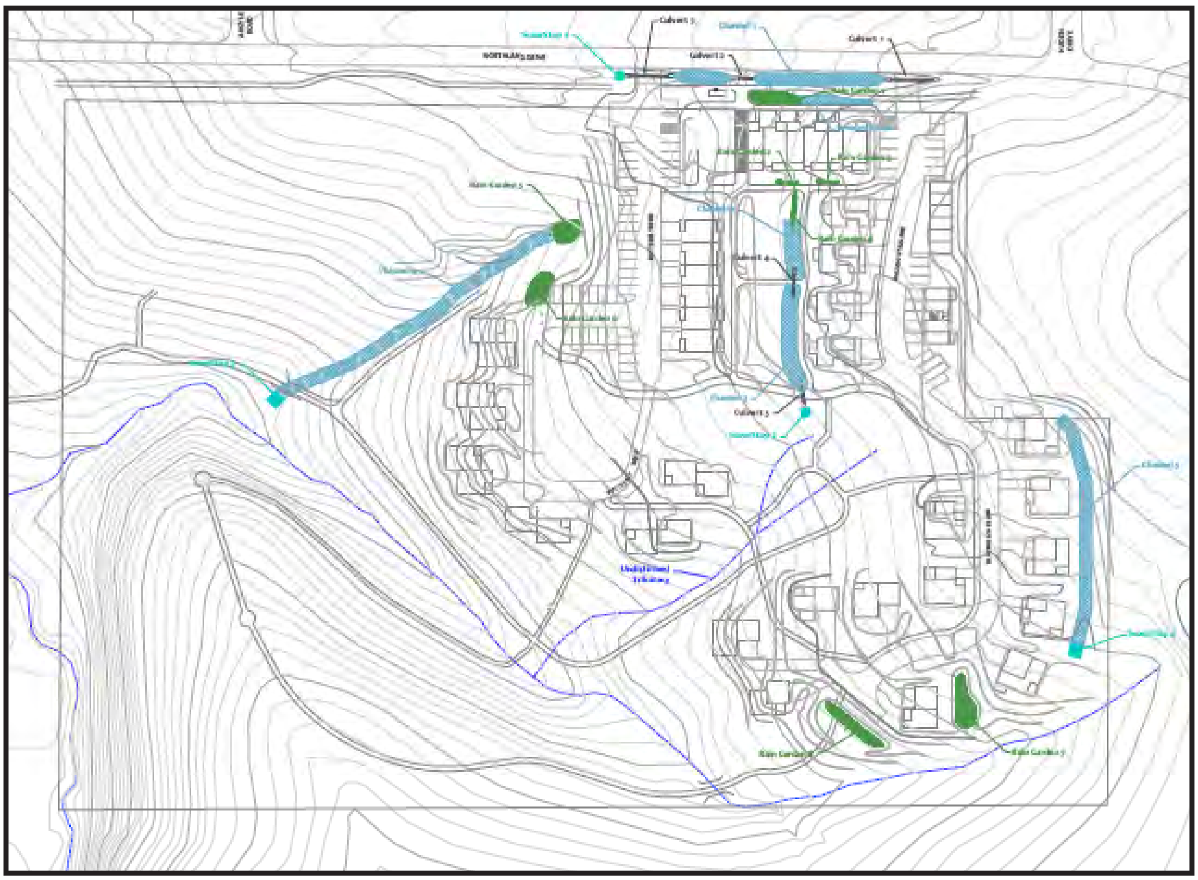


Figure 3.1 Proposed Bear Creek Prairie Project, Columbia, MO. Source: Andy Guti

Conventional Site Development Plans showing a minimum of stormwater controls can still provide opportunities for SWPPP preparers and contractors to incorporate environmental features that will enhance the protection of water resources, as well as improve the project's overall success. For example, in a conventional Site Development Plan, a choice can be made to use more than one small sediment pond or a series of other small depressions to catch sediment. Additionally phase land disturbance in order to minimize sediment-laden runoff. Better success in reducing sediment laden runoff will be achieved by focusing more effort on erosion control than on sediment capture. Regarding redevelopment projects, Environmental Site Design features may include planter boxes and street edge bioswales. Steps for incorporating these elements into the Stormwater Pollution Prevention Plan and ensuring their protection during development are described in more detail in Chapter 4.

Earlier chapters explain when stormwater control practices are installed in accordance with good environmental principles, they will not only benefit the environment, but they will improve overall use and enjoyment of the development site and increase property values. Well-designed practices can also reduce project costs by reducing site maintenance requirements. Preparers and contractors can maximize these benefits when writing and executing the project's Stormwater Pollution Prevention Plan.

Increased Use of Environmental Site Designs

The number of development designs incorporating environmental features is growing. It is a trend that contractors will notice, if they are not already aware of it. The trend has led to the creation of the Environmental Site Design, used by developers to serve the growing public demand for environmental features. Environmental features are designed into the initial site development plan (concept) and carried through to the final site improvement plan. Stormwater Pollution Prevention Plan preparers and contractors familiar with these special design features are better prepared to properly select and install them. The Environmental Site Design approach is rapidly being adopted across the nation, because conventional stormwater management has been shown to significantly increase the volume and velocity of stormwater runoff, resulting in flooding, eroded properties and diminished fishing, swimming and drinking water resources.

Stormwater Pollution Prevention Plan preparers and contractors who understand the purpose and function of environmental features will be able to assist communities and developers in maximizing their benefits. For example, capital project costs can be reduced through the Environmental Site Design that employs less asphalt, fewer curbs and fewer pipes. The resulting landscape features will add value of interest to the buyer. Those benefits extend to construction contractors as well.

Contractors well versed in environmental site design goals and protection measures have an employable advantage over those who do not. And, their success in implementing Environmental Site Design features depends on an understanding of their benefits and contributions to the overall development goals. The following sections are devoted to explaining the important site development principles essential to achieving an effective Environmental Site Design. While these ideas are directed more toward a community leader or developer with environmental site design goals, the same principles apply throughout project implementation. The contractor's awareness of them will improve his or her ability to offer feasible adjustments to improve a site design at any stage of project development. An understanding of these goals will also help the contractor avoid costly mistakes. For more information about environmental site design, see references including *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011*.

Environmental Site Design Principles and Features

When projects are conceived, the business interest is usually clearly understood. Therefore, it is important to recognize the financial benefits of environmental site design such as reduced capital expenditures, lower escrow requirements and increased property values. In order to avoid costly repairs or risk environmental fines, general contractors may require written agreements that hold subcontractors and field personnel responsible for protecting environmental design components and practices.

A greater challenge in integrating environmental features may be in understanding the benefit and function of the site's natural attributes (geology, soils, vegetation, drainage patterns, etc.) toward the project's design. Through careful research and planning, natural systems, such as streams, undisturbed green space, wetlands and riparian areas, can be maintained, restored or enhanced to function as efficient stormwater management features. They are nature's stormwater management system and should be preserved and used as cost-effective measures.

Building man-made runoff control devices as opposed to preserving the natural stormwater systems not only requires additional capital investment, but also eliminates highly valued resources and can ultimately result in costly streambank restoration projects. In addition, it automatically ties the community to ongoing maintenance responsibilities that can be a source of major expense long after the developer is gone.

Communities, developers and contractors wanting to effectively implement environmental features may benefit from managing their projects after adopting these three basic goals in controlling site runoff:

- **Mimic the natural patterns and processes.** Prior to new development, the rainfall-runoff process is slow because precipitation falls on vegetation and native soils whose horizons have not been disturbed. This allows a large portion of the precipitation to infiltrate. Runoff also tends to follow relatively long pathways across vegetated areas prior to entering streams. Stormwater management practices should try to mimic these processes as land is newly developed. This practice improves water quality, but can also reduce the overall cost of managing stormwater.

- **Maximize infiltration.** Impervious surfaces, such as roadways, parking lots and rooftops, eliminate the infiltration process. Further, they tend to channelize runoff which increases runoff, volumes and rates. Conventional curb and gutter systems compound the effects. As a result, unfiltered pollutants are carried directly and rapidly to the streams. By minimizing impervious surfaces, the volume and flow rates can be curtailed, thereby reducing threats of increased flooding, channel erosion and impaired water quality.

- **Preserve natural areas.** Increasing green space in community design and connecting it where possible optimizes the opportunity for best stormwater management. Connecting these spaces to preserved natural areas adds even more value to stormwater management and recreational opportunities. If large or connected green spaces are preserved or created as in exchange for reduced lot sizes and structures, requirements for roads, sewers, water lines and other infrastructure can also be minimized.

Adopting these goals early in project planning will create the most opportunity to guide environmental design options that mesh well with development goals. A development embracing these goals will suffer less interruption or damage to infrastructure caused by stormwater during and after construction. In addition to the lower infrastructure costs, a well-designed site will hold higher value to its owner and user because of the quality and stability of its environment.

Following is a list of features that might appear in an environmental site design and its narrative plan and is intended to complement or supplement requirements to be outlined in the Stormwater Pollution Prevention Plan. These suggestions are intended to introduce the contractor to the types of Environmental Site Design stormwater controls often applied at construction sites. The contactor should consider the specific conditions at the site before implementing each practice. Chapter 6 explains how various practices can be installed to complement the site conditions. The Environmental Site Design and its narrative plan may:

- Designate areas with severe limitations such as floodplains, steep slopes, drainageways, existing bodies of water and unstable soils. Leave these areas undisturbed and to be used as green space to protect water quality. Check local ordinances and permits for limitations of construction in floodplains and near waterways.

- Identify natural vegetation and trees to be left undisturbed during construction or during certain phases of construction. Existing areas of grass, shrubs and trees will provide natural erosion and sediment control while enhancing the attractiveness of the project. Check local ordinances for stream corridor setbacks. In some cases, these areas can also be enhanced to help meet water quality protection requirements for both construction and post-construction runoff control.

Sequence earth grading and other site preparation so these activities are minimized.
The narrative Environmental Site Design plan may also refer to the numerous resources on contemporary green infrastructure and low impact development designs. Such designs may make it easier to comply with federal, state and local requirements to protect water quality. More information is available about how these contemporary practices may even minimize project costs. See references, including *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011*.

- Specify rough grading in phases to keep disturbed areas small and to minimize the amount of time soil will be bare of vegetation. The discharge permit required for land disturbance states: “Where soil disturbing activities cease in any area for 14 days or more, the permittee shall construct and install best management practices to establish interim stabilization. If the slope of the area is greater than 3:1 or if the slope is greater than 3 percent and greater than 150 feet in length, then the permittee shall establish interim stabilization within seven days of ceasing operations on that part of the site.”

Plan for the installation of best management practices (see Chapter 6 - Practice Installation and Maintenance) to control overland sheet flow, limit erosion and keep sediment and other pollutants on the site.

- When planning for best management practices near streets, ensure practices are designed and installed in a manner that prevents major flooding, sediment accumulation, traffic interruptions, road damage or other off-site impacts during significant storm (design) events.

- Require topsoil to be stockpiled and protected from erosion so it may be available for spreading over the areas to be permanently vegetated during final grading. Protecting topsoil helps maintain its organic matter, microorganisms and nutrients for successful vegetation establishment.

- Schedule the installation of control measures, such as best management practices prior to land disturbance. It is very important to understand the ultimate plan for post-construction runoff to effectively plan, prepare, schedule and coordinate conversion from construction site best management practices to permanent practices. Schedule the installation of post-construction stormwater control measures after the site is stabilized. There should be no potential for erosion on the site or sediment discharge into the post-construction stormwater control measures, unless they are intentionally designated to serve as temporary practices.

- Provide for operation and maintenance of the permanent, post-construction stormwater control measures after the site is stabilized. If selected, designed, installed and operating properly, these structures will provide storm water quantity and quality protection after the construction phase of the project is complete.

Midwest Examples of Green Infrastructure

Some developments throughout the midwest have incorporated the principles of green infrastructure and low impact development in an effort to mimic or enhance the preconstruction hydrology conditions of the area. For example:

Alberici Corporate Headquarters, Overland, MO

Figure 3.2 Alberici Headquarters Source: Alberici Headquarters

This Brownfields redevelopment project includes the reuse of a 1950s office building and a 155,633 ft^2 former metal manufacturing facility. The 13.6-acre site originally had 9 acres of impervious surface, including 3.7 acres under roof. The restoration process began by reducing pavements to a bare minimum. The development footprint was a fraction of that allowed by local zoning. This suburban, Brownfield site was restored with native, drought-resistant plantings, including six acres of Missouri prairie grass and wetland plants. More than 250 native trees and 4,200 perennial plants and bushes were planted, placed by type, growth rate and shade requirements. The site has become a seed bank for the St. Louis area, providing the resources to establish other native landscapes. This Brownfields site is a great example of what can be done to return an eyesore to an ecologically sensitive property in an industrial environment.
www.epa.gov/greenkit/stormwater_studies/Alberici_MO.pdf

Heifer International Headquarters – Little Rock, Arkansas

Figure 3.3 Heifer International Headquarters, Little Rock, Arkansas Source: Timothy Hursley

Located next to the Clinton Presidential Library, the Heifer International Headquarters is in walking distance of busses, a new light-rail system and a pedestrian entertainment district.

Environmental Aspects

- A restored wetland that wraps around three sides of the building collects stormwater for reuse as irrigation water.
- Rainwater collected from the roof is stored in a five-story water tower wrapped with a fire stair.
- Graywater collected from sinks and drinking fountains, condensate from outside air units, and rainwater from the water tower are reused in the toilets and cooling tower.
- Moisture removed from the building as condensate is reused to cool the building. Waterless urinals and low-flow toilets and lavatories further reduce potable water use.
- The narrow, semicircular floor plan provides daylight and views for all employees. The majority of open offices in the building offer river views and northern light, and all major gathering spaces access the exterior. Five balconies on each floor, designed as outdoor conference rooms, hang over the wetland and act as sunscreens.
- The building was designed to use up to 55 percent less energy than a conventional office building and to last for at least 100 years.
- Materials were selected for their durability, maintainability, low toxicity, recycled content, and regional availability. www.aiatopten.org/hpb/overview.cfm?ProjectID=781

The Wilderness - Overland Park, Kansas

This multi-phase development located in southern Overland Park- Johnson County, Kansas offers various housing types among trees and natural areas. A 12-acre city park is located nearby that offers a 5-acre stocked fishing lake. Paved trails lead to 400-acre deed restricted Nature Preserve with lakes, trails, land and wildlife. www.cottagesatthewilderness.com

Oakbrook - Clay County, Missouri

The Oakbrook development is the first low impact development in Clay County, Missouri. The development places emphasis on conserving the area's natural resources. The development is currently 156 acres that consist of one to two acre lots, 54 acres of dedicated open space. Walking trails and rain gardens are located throughout the development.
www.oakbrookliving.com

Bear Creek Prairie - Columbia, Missouri

Bear Creek Prairie is a proposed 17-acre conservation development. The development is designed to follow the principles of the conservation community concept, where homes are generally clustered around common green spaces that everyone can use and enjoy. This encourages interaction among residents while retaining use of wooded and open areas for trails, gardens, gathering areas and other amenities.

The City of Columbia permits Planned Unit Developments, or PUD districts, which provided the vehicle for the project if it is built as planned. This zoning will allow the developers to accomplish the conservation community concept. Figure 3.4 shows the development's proposed site plan.

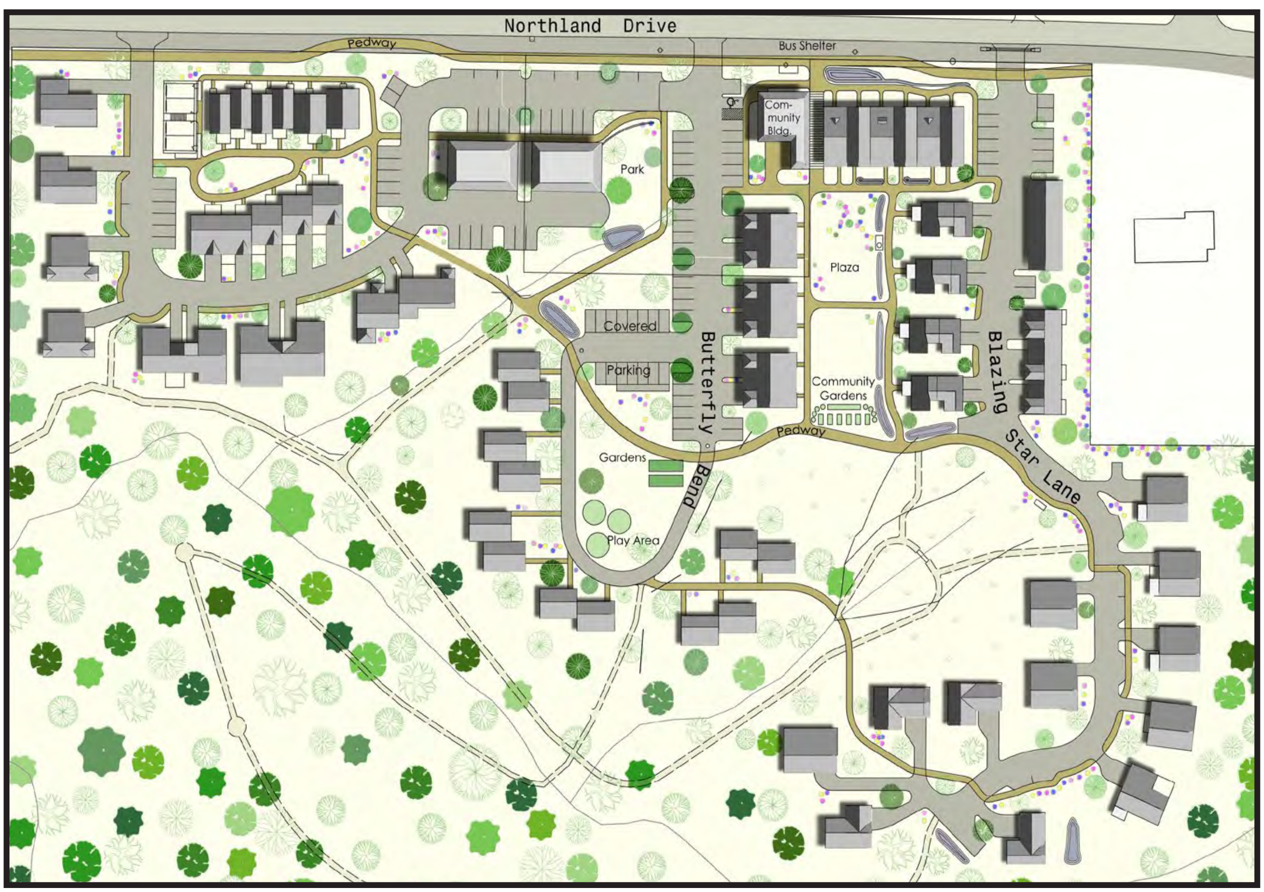


Figure 3..4: Bear Creek Prairie Proposed Development Site Plan. Source: Andy Guti www.bearcreekprairie.com

Fields Neighborhood - East Troy, Wisconsin

This development in southern Wisconsin is a new nature-based community that combines sustainable living with a strong community atmosphere and respect for the natural environment. The development offers a range of clustered condominiums integrating the latest green building technologies with designs minimizing the impact on the natural surroundings. After completion, the development will feature 74 units of clustered condominiums on 17-acres. Figure 3.5 shows a rain garden on a property in Fields Neighborhood. www.fieldsneighborhood.org

Figure 3.5: Fields Neighborhood Rain Garden Source: www.fieldsneighborhood.org

Legacy Trails, Habitat for Humanity- Springfield, Missouri

The goal of this 18-acre development is to provide homes for 56 families and to enhance the quality of life for residents as well as protect the quality of the environment, featuring:

- Native plants and grasses.
- Innovative, energy-efficient home design.
- Natural walking paths.
- A savannah-like community park.
- Curbless streets to limit stormwater runoff.
- Limited on-street parking to increase safety and reduce crime.

In December 2008 the Missouri Conservation Heritage Foundation awarded Habitat Springfield a $5,000 grant helping fund a native plant, rain garden project at Legacy Trails. The bio-retention areas have proven successful in helping manage stormwater runoff quality. www.habitatspringfieldmo.org/legacytrail.html

Prairie Crossing- Grayslake, Illinois

Figure 3.6: Prairie Crossing Homes Source: www.planningwithpower.org

This development is one of the most popular conservation design communities in the nation, and is considered a national example of how to plan our communities to enhance the environment and support a better way of life. The development is located in Grayslake, Illinois, a suburb of Chicago. The community was designed to combine the preservation of open land, easy commuting by rail and responsible development practices.

More than 60 percent of the 677-acre site is protected open land actively used by people and wildlife. Ten miles of trails wind through a landscape of farm fields, pastures, lakes and ponds, native prairies and wetlands.

The development is well known for its beautiful native prairie landscaping. With more than 165 acres of restored prairies, 20 acres of restored wetlands and 16 acres of historic hedgerows, the Prairie Crossing landscape is contributing to the restoration of the native ecology of the region. Many Prairie Crossing residents integrate these native plant communities into their own landscaping. Figure 3.6 shows some of the homes located in the development.
www.prairiecrossing.com

Combining Stormwater Treatment Practices

Each stormwater control measure has unique characteristics and can be used to target specific pollutants. For example, some practices will collect sediment, whereas other practices are preferred for treating phosphorus. (See Appendices C and D for resources that provide specific pollution control information, such as the International BMP Database and the SUSTAIN model.)

The preferred approach for maximizing water quality improvement is a combination of stormwater control measures that collectively address the source of pollutants, the conveyance of stormwater and the infiltration and treatment of runoff. This series of measures, sometimes referred to as a "treatment train" or "string of pearls", typically includes an integrated set of biological and physical treatment steps that successively remove pollutants from stormwater runoff. The components of a combination approach are designed to treat stormwater runoff for water quality benefits and to reduce stormwater runoff peaks and volumes. Source controls, upstream of the initial structural components are an important component to maximize benefit.

The combination approach typically follows a hierarchy of practices in a sequenced approach. The stages of a combination approach incorporate the following components:

- Preservation or restoration of open space and natural drainage areas and their native or adapative vegetation.
- Dispersion of small-scale, on-site source controls such as rain gardens and other practices that provide infiltration and evapotranspiration (see Glossary).
- Conveyances such as swales and filter strips that connect on-site controls, dissipate energy and filter larger particles.
- Filtration stormwater control measures such as bioretention and wetland swales.
- Provisions for overflowing or rerouting large storm events.

Receiving Waters

A designer should understand the site conditions and hydrologic characteristics of the drainage area and the requirements for water quality treatment before choosing a sequence of treatment practices. The developer and site design team should select a combination of practices to meet water quality goals, while meeting local requirements and objectives. Preserving native areas or establishing vegetated open space is commonly the first step of a combination approach. Undisturbed land and areas landscaped with native plants increase stormwater infiltration and can help minimize runoff, erosion and potential for downstream pollution.

Developments may have design or site constraints limiting the amount of open space available for stormwater management. These sites may require some engineered stormwater infiltration practices and treatment.

Stormwater control measures, such as pervious vegetated areas, infiltration trenches and rain gardens, provide treatment and control of runoff near its source. Site characteristics, such as area, soil type or topography, may limit the effectiveness of open space and infiltration practices.

Engineering filtration systems are the next step of the combination approach. Filtration systems, such as bioretention and vegetated swales, have the capacity to detain smaller rain events and are designed to treat the water quality volume.

Larger scale stormwater detention practices should be the last stage of the combination approach. Detention generally applies to dense developments and provides a solution for damaging storms larger than the water quality event. Detention basins manage the rate of stormwater discharge from larger rainfall events. Some also include a treatment component sized for the water quality event. If detention basins are needed, their size may be minimized based on the combination of on-site practices that also provide for volume control.

The following examples demonstrate how a combination approach may be incorporated at three different sites:

Scenario 1: New Residential Subdivision

- Preserve a native prairie remnant or other unique landscape feature as common open space.
- Landscape with native or adaptive vegetation and incorporate rain gardens on each lot (or a group of lots) to disconnect downspouts.
- Design vegetated swales to convey and treat runoff from landscaped yards and streets.
- Limit impervious area for the development by limiting street width and the use of cul-de-sacs (provide narrower through-streets to accommodate emergency vehicles), using pervious pavement, limit on-street parking to one side, etc.

Scenario 2: Commercial Development

- Establish native or adaptive landscaping in and around buildings and parking areas.
- Use best parking lot designs to minimize impervious surface, including intra-lot bioswales or dispersed rain gardens below.
- Use bioretention cells and porous pavement to treat and infiltrate parking lot runoff.
- Use green roofs to reduce runoff from “flat” rooftops.

Scenario 3: Office Park

- Identify source controls and maintenance practices that decrease roadway salts and fertilizer use.
- Place filter strips around building downspouts and parking lots, leading to infiltration basins.
- Use dry swales to treat runoff from streets and convey to a wet pond or detention.
- Install a cistern to use for irrigation, lawn watering or other purposes.

Proper maintenance and pollution prevention practices can further limit stormwater runoff pollution. Maintenance of stormwater control measures to remove pollutants and sediment is critical to continued success. Pollution prevention strategies are specific to the site management practices and may include containment barriers around chemical storage areas, vehicle maintenance to prevent leakage or maintenance practices that reduce salt or fertilizer application.

The next chapter presents information to assist in preparing a SWPPP. Preparers should occasionally revisit this chapter while preparing the SWPPP. For more information about environmental site design, see references including *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011*.

CHAPTER 4
STORMWATER POLLUTION PREVENTION PLAN OR EROSION AND SEDIMENT CONTROL PLAN

Purpose

A stormwater pollution prevention plan, or SWPPP, is required under all Missouri land disturbance general permits. Some local governments also regulate land disturbance activities and therefore require a SWPPP or what they may refer to as an Erosion and Sediment Control Plan. The purpose of a SWPPP is to identify possible pollutants that may enter stormwater runoff and to identify best management practices, or BMPs, that will minimize or eliminate possible water quality impacts from stormwater runoff. BMPs are physical, structural or managerial practices that prevent or reduce pollution. Best management practices may be used when used singly or in a combination to produce the desired level of results.

A SWPPP must be developed for each construction project subject to regulations and mustbe prepared prior to any land disturbance. The SWPPP will define and schedule the erosion, sediment and good housekeeping control measures to be used on the construction site to prevent or minimize erosion that could occur and keep sediment and other pollutants from exiting the site.

It is stated in the Missouri land disturbance general permit: "...before disturbing earth, or submitting an application, the permittee must develop a SWPPP specific to the land disturbance activities at the site. This plan must be developed before permit coverage can be issued. The permittee must fully implement the provisions of the SWPPP required as a condition of this general permit throughout the term of the land disturbance project."

In all cases, the permittee and their representative or the contractor(s) responsible for installation, operation and maintenance of the best management practices must have a current copy of the stormwater pollution prevention plan with them when on the project site. In some cases, the permittee may be required to submit a copy of the SWPPP to the Missouri Department of Natural Resources or the local government office. The Missouri Land Disturbance General Permit requires a copy of the stormwater pollution prevention plan be provided to all contractors responsible for installation, operation or maintenance of any best management practice.

Chapter 1 contains information on regulations and permits. The Missouri Department of Natural Resources' regional office may be contacted for additional information.

The Plan

The stormwater pollution prevention plan should serve as a guide for the selection, location, installation and maintenance of practices to control all anticipated erosion and prevent sediment and other pollutants from leaving the site. A SWPPP is an evolving document that includes text, site maps and forms that are maintained and updated throughout the construction project as the construction site evolves. The requirements for what information must be included in the stormwater pollution prevention planare located within the Missouri land disturbance general permit. If a construction project is within a community that also regulates land disturbance, the contractor will need to include their SWPPP guidelines.

The following items are typical components required in a SWPPP:

- Identification of the person responsible for implementing the SWPPP.
- Physical and environmental description of the site including soils, slopes, vegetation and water resources.
- Description of the construction activity.
- Description of the potential for discharge of sediment and other pollutants from the construction site.
- Narrative, plan sheets and construction details and specifications for erosion, sediment and good housekeeping controls.
- Narrative describing the timing and schedule of installation of erosion, sediment and good housekeeping controls.
- Methods used for final stabilization of all exposed soil areas (should be coordinated with post-construction plans during the initial site design process and again before implementation).
- Information related to conformance with wetland permits (if applicable), the need for environmental review or results of such review, impacts of discharges on endangered or threatened species, and impacts of discharges on historic places or archeological sites.
- Site map showing the following information:
    - Location of areas not to be disturbed.
    - Limits of disturbed area.
    - Location and type of temporary and permanent BMPs.
    - Existing and proposed grades with direction of stormwater flow information before and after construction.
    - Impervious surfaces and soil types.
    - Location of construction phasing.
    - Location of surface waters (e.g., streams, lakes, wetlands) within 0.5 mile of the project.

Developemnts in an area draining to a water body that has been listed on Missouri's impaired water body list (a list required by Section 303(d) of the Clean Water Act), special measures may need to be taken to ensure conformance with the required total maximum daily load, or TMDL,

implementation plan. Contractors can determine if the stream might be included in an active TMDL restricted stream by contacting the Missouri Department of Natural Resources or by viewing EPA's approved TMDL list available on the Missouri Department of Natural Resources Web site at www.dnr.mo.gov/env/wpp/waterquality/index.html

Note: After a TMDL has been approved by EPA, the stream will ultimately removed from the impaired water body list. While the water body may still be impaired, it is moved to the TMDL implementation list. The TMDL implementation document then becomes the governing document for addressing the impaired waters.

Understanding the Site Plan and Design

The land site should have desirable natural drainage and soils with good potential for the intended development. Detailed soil surveys and geological investigations should have been completed to assess the suitability for the intended development.

Designate areas on the site map with severe limitations such as floodplains, steep slopes, drainageways, existing bodies of water and unstable soils to be left undisturbed and used as green space to protect water quality. Check local ordinances for limitations of construction in floodplains and near waterways.

Designate natural vegetation and trees to be left undisturbed during construction. Existing areas of grass, shrubs and trees will provide natural erosion and sediment control while enhancing the attractiveness of the project. Check local ordinances for stream corridor setbacks. In some cases, these areas can also be enhanced to help meet water quality protection requirements for both construction and post-construction runoff control.

The site development should been designed so that minimum earth grading and other site preparation is required. Opportunities should be sought to speed up the design approval process by making the design meet the intentions of the municipality's comprehensive or watershed management plan to protect natural resources. Also refer to the numerous resources on contemporary green infrastructure and low impact development designs. Such designs will help the contractor comply with federal, state and local requirements to protect water quality. Much information is available on how these contemporary practices may even minimize your project costs. There are additional resources listed at the end of this chapter.

Rough grading should be completed in phases to keep disturbed areas small and to minimize the amount of time soil will be bare of vegetation. The permit states: "Where soil disturbing activities cease in any area for 14 days or more, the permittee must construct and install BMPs to establish interim stabilization. If the slope of the area is greater than 3:1 or if the slope is greater than 3 percent and greater than 150 feet in length, then the permittee must establish interim stabilization within seven days of ceasing operations on that part of the site."

The SWPPP must present a plan for the installation of best management practices (see Chapter 6 - Practice Installation and Maintenance) to control overland sheet flow, limit erosion and keep sediment and other pollutants on the site.

Topsoil should be stockpiled and stabilized to protect it from erosion and then, following final grading, spread over the areas to be permanently vegetated. Topsoil is rich in organic matter, microorganisms and nutrients for successful vegetation establishment.

The SWPPP must contain a schedule for the installation of best management practices. The installation of best management practices should occure in concert with the development

schedule. All best management practices should be in place prior to any disturbance in the area they protect. It is very important to understand the ultimate plan for post-construction runoff to effectively plan, prepare, schedule and coordinate conversion from construction site BMPs to permanent practices. Contractors should schedule the installation of post-construction BMPs after the site is stabilized. There should be no potential for erosion on the site or sediment discharge into the post-construction BMPs.

Provide for operation and maintenance of the permanent, post-construction BMPs after the site is stabilized. If selected, designed, installed and operating properly, these structures will provide stormwater quantity and quality protection after the construction phase of the project is complete.

Developing the SWPPP

Information that Goes in the SWPPP

The SWPPP, or erosion and sediment control plan, has many sections of information in it. The appropriate Missouri Department of Natural Resources general permit for land disturbance and local ordinances should be reviewed to make sure all required information is included in the SWPPP. Table 4.1 provides a checklist of information to be included in the SWPPP. The text column refers to the narrative portion of the document. The site maps are the drawings within the SWPPP. The forms are those documents created as required in the general permit. Each control measure should provide installation and maintenance information, which should be found on the detail sheet. Refer to Chapter 6 for a list of all best management practices.

Table 4.1 SWPPP Checklist of Requirements

Information Required	Sections within the SWPPP			
	Text	Site Map	Forms	Detail Sheet
Site Description (e.g., soils, topography, vegetation)	X			
Discharge Points and Receiving Waters	X	X		
Limits of Disturbance – permitted boundary		X		
Temporary BMP's				
Description of installation and maintenance	X			X
Description of where and why used	X			X
Location		X		
Removal or conversion of controls with site stabilization	X			
Permanent BMPs				
Description of when to install - schedule	X	X		X
Location		X		
Good Housekeeping BMPs	X	X		X
Inspection of all BMPs – when and how	X		X	X
Sequencing and scheduling of work with BMP installation	X	X		
Amending and Updating the SWPPP	X	X	X	
Public Notification	X	X	X	
Contractor Responsibility	X			
Site Stabilization and Termination of Permit Coverage	X			

The following tables also provide questions and goals to set during the design of the construction project. Table 4.2 provides questions on the existing natural resources to be shown on the plan. Table 4.3 provides site development goals to strive for during the design of the construction project.

Table 4.2: Existing Natural Resource Considerations

Natural Resource	Questions	Actions
Wetlands	Are wetlands on-site? Are permits needed (e.g., 404/401 permits) from the Army COE or Missouri Department of Natural Resources?	Show all wetlands on map. Obtain COE/ Missouri Department of Natural Resources permits or documentation before plan approval.
Streams and Floodplains	Are major waterways on the site? Are permits needed from the Army COE or Missouri Department of Natural Resources? Is the site located within the 100- or 500-year flood plain? Is the municipal or county stream buffer (setback) shown? Is the site in a flooding or erosion prone area?	Show major waterways. Obtain COE/ Missouri Department of Natural Resources permits or documentation before plan approval. Obtain local floodplain Development Permit if applicable Show 100- and 500-year flood plains on map. Show stream buffer. Show areas prone to flooding. Show stream bank erosion areas.
Karst	Are sinkholes, springs or seeps located on the site? What is the depth to bedrock?	Local buffer requirements may apply and should be shown. Show sinkholes, springs, seeps and other karst features. Show areas with shallow depth to bedrock.
Existing Topography	What is the existing topography? Are there areas with slopes steeper than 20 percent? What are the site's soil types? What is the existing stormwater drainage area and flow path?	Show existing topography, identify areas with slopes greater than 20 percent. Show site soil type. Show areas with erodible soils. Show gullies, swales, ditches, etc.
Ponds	Are there existing ponds on or adjacent to the property? Does the pond provide recreational benefits? Does the pond provide flood detention benefits? What is the condition of existing ponds (i.e., depth of sediment in pond, bank erosion, invasive plants)?	Show all ponds on map, including any existing detention basins.
Vegetated Cover	Is the site forested? Are grassy/prairie areas on the site?	Show forest and prairie areas. Show large trees (>12" diameter).
Existing Property Use	What is the site's current use? What buildings, structures and other impervious surfaces are present? Are there utilities through the site?	Show existing impervious areas and utilities.
Surrounding Property Use	What is the surrounding property use?	Show property boundary and surrounding property uses.

Table 4.3: Site Development Goals, Questions and Methods

Goal	Questions	Methods (To the Maximum Extent Practicable)
Minimize the Generation of Stormwater Runoff	Can land disturbance be minimized? Can additional green space be preserved? Can proposed development be located in already developed areas?	Limit clearing, grading, and earth disturbance. Use clustered development with open space designs. Use narrower, shorter streets, right-of-way and sidewalks. Allow smaller radii for cul-de-sacs. Reduce parking space requirements. Preserve and protect forested areas, especially areas with large trees. Show tree preservation areas on plans. Allow for shared driveways and parking areas. Provide incentives for site redevelopment.
	Can stormwater safely flow overland to buffer areas (i.e., avoid piping)?	Grade to allow stormwater to sheet flow into buffer or conservation easement areas. Limit use of curb and gutter streets. Use grass channels for street drainage and stormwater conveyance. Allow roof downspouts to flow overland into vegetated cover.
	Can stormwater be captured and infiltrated into the ground?	Rainwater infiltration systems. Examples include rain gardens, dry wells and other landscape infiltration methods. Emphasize managing stormwater at the point of generation.

Determine Limits of Disturbance

The SWPPP must show the limits of disturbance by outlining all areas on the site map where soil will be disturbed or vegetative cover removed. These areas will require erosion and sediment control best management practices. The permitted limits of disturbance must include all areas of soil that will or may be disturbed to complete the construction project. This includes parking and lay down areas, equipment and material staging or storage areas and areas where the contractor will store borrow or fill material. The SWPPP must also outline areas to be left undisturbed and the locations where protective fencing needs to be installed.

Determine Drainage Areas

When beginning the erosion and sediment control design of a construction site, the contractor should first look at the drainage patterns over the site. If there is land uphill of the site with the potential to discharge stormwater onto the contractor's site, the contractor should decide whether or not to accept the discharge and whether or not to design controls for the additional area. If the contractor wishes the design to be solely for the stormwater coming from their permitted site, then you must design diversions for the discharge above your site. These diversions are the very first controls put in place and must be totally stabilized prior to any stormwater being allowed to flow into, through or discharge from them. The diversions must not increase the amount of sediment being discharged from the site.

The SWPPP must separately outline all of the drainage areas that occur on the site. The SWPPP must also identify all of the locations where stormwater is discharged off the development site throughout the entire construction project. Furthermore, the SWPPP must identify the points where the development site will discharge stormwater into natural water ways and identify the distance from the permitted limits of the construction project to the water body.

Select Specific Control Measures

Four areas of concern should be evaluated for each drainage area: soil stabilization (erosion control), runoff control (sediment control), pollution prevention and permanent or post-construction runoff controls. Specific practices to control these areas are described in Chapter 6 - Practice Installation and Maintenance. As control measures are selected, identification symbols and a symbol legend should be placed on the site map. Drawings and specifications for all structural practices and vegetation specifications should be included in the plan including information on proper installation, maintenance and inspection of each control measure. Temporary controls need additional information as to how and when the control is to be removed and the area stabilized.

Soil Stabilization/Erosion Control

Erosion control devices include vegetation, mulch and compost, rolled products such as blankets, and any other device that is laid on the disturbed soil surface to cover and protect it from raindrop impact and wind erosion. These devices dissipate the energy from the wind and rain so soil particles are not dislodged and moved in the stormwater flow.

Runoff/Sediment Controls

Sediment control devices slow the stormwater flow and/or temporary pool the flow to dissipate the energy of the flowing water. Slowing the flow reduces the water's capacity to transport sediment off the site. Devices effective at reducing flow velocity include silt fences, wattles, inlet protection, sediment traps and ponds, check dams, etc. When using these devices for sediment control on the construction site, contractors should consider the effects that temporary pooling of water, or flooding, may have on areas adjacent to the pooling device.

Pollution Prevention

These devices and practices cover good housekeeping, construction exits, concrete washout, masons area, etc. Good housekeeping includes the management of solid waste (trash and debris), sanitary waste, petroleum-based products and hazardous waste. The SWPPP must identify controls for these possible pollutants on the construction site and their proper inspection and maintenance. The SWPPP also must identify the reportable quantities for petroleum and hazardous waste products and discuss the use of a spill kit on the construction site.

Post-Construction Control Measures

It should be stated whether the control is temporary or permanent within the description of each control device. Structural controls that are permanent must also include information on the operation and maintenance of each control after the construction project is complete and the site is fully stabilized. Maintenance requirements should be explained in the post-construction section with the SWPPP. See Chapter 3 for considerations on permanent stormwater control measures.

These permanent devices are not designed for control of sediment as a post-construction device so they should not be put into permanent use until the site is fully stabilized and there is no threat of erosion or sediment discharge from the site. If devices are to be used during both stages of construction, the device must be fully cleaned of sediment deposits and retrofitted as a post-construction device after the entire site is fully stabilized and there is no hazard of soil erosion occurring. It is very important to coordinate transition from construction site best management practices to post-construction stormwater control measures, especially where newer green infrastructure and low impact development practices will be installed.

Schedule Construction, Stabilization, Inspection and Maintenance Activities

The three main scheduling items required are a construction schedule, a stabilization schedule and an inspection and maintenance schedule. A schedule should also be followed for terminating the project and closing out the permit.

Construction Schedule

The construction schedule must explain in an orderly fashion what will occur from the beginning to the end of the project. This includes both the sequence of the land disturbing activities and the sequence of controls that need to be in place before each of those activities begin. The installation sequence of control practices and structures is a critical factor in controlling erosion and sediment loss on the construction site.

Phasing of site grading is an important element of the schedule. Sediment basins, diversions and conveyance systems, whether temporary or permanent, should be installed either before grading begins or very early in the rough grading process. These practices must be stabilized immediately after they are constructed in order for them to function properly and to prevent structure failure leading to additional erosion and sediment discharge from the site. The sequence of rough grading and temporary stabilization should be indicated for each area to be graded.

The schedule should indicate the control practices to be used if grading is suspended for an extended period of time (seven to 14 days or more depending on slope and distance to waterway). In areas without sediment traps, temporary structures to divert water from cut and fill slopes, temporary seeding with mulch and tackifier or other practices should be used to stabilize the exposed soil surface.

The SWPPP must indicate the planned times and practices for final stabilization, using seed with mulch or using sod. Final stabilization should occur as soon as practicable following final grading.

Stabilization Schedule

The stabilization schedule shows the allowable times for seeding and placing sod to ensure successful vegetation establishment and soil protection (See Temporary and Permanent Seeding). An example is shown in Table 3.1. It should identify the plant species or variety, seeding dates and seeding rates. If alternate species or times are listed, this chart can be used to schedule soil surface protection activities even if the planned construction schedule falls behind. The stabilization schedule should follow closely with the construction schedule. The seeding schedule may also provide for temporary stabilization with annual ryegrass or tackified mulch, if grading is unexpectedly suspended and a permanent seeding cannot be established.

Table 4.1 Example of a Seeding Schedule

Stablization Type	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT
Permanent Seeding with Mulch Turf fescue: 80 lbs/acre								
Temporary Seeding with Mulch Annual Ryegrass: 75 lb/acre								
Mulch with Tackifier (no seed)								
Fescue or Zoysia Sodding*								

* Ground must be moistened to cool soil temperatures before sod is laid. Use only fresh, good quality sod. Irrigate to soil depth of 4 inches immediately after installation and for the first four weeks, or until sod is well established.

Table Key
- Optimum Seeding Times
- Acceptable Seeding Times

Information on seeding rates and types of vegetation is available in Chapter 5 within Table 5.3. You may also contact your county soil and water conservation district for proper vegetation and seeding rates for your area. Remember, you may need to modify the seeding information provided in the SWPPP if the construction schedule changes, therefore changing the time of year you will be installing temporary or permanent vegetation.

Inspection and Maintenance Schedule

The inspection and maintenance schedule is a plan for all temporary and permanent erosion, sediment and stormwater control measures throughout the construction project. This written plan should specify the inspection programs as required in the general permit. It should indicate the work materials and equipment to be used, who is responsible and when inspections and maintenance will be provided.

Inspections are necessary immediately after each phase of construction and storm event, as well as periodic inspection and maintenance to ensure proper functioning of control measures. You should schedule inspections after every rain producing runoff for controls that detain, store or convey stormwater. Work time should be accounted for in the schedule to make immediate repairs to damaged areas and control structures.

Inspection and maintenance should be scheduled for structures such as sediment basins and ponds that require regular cleanout in order to keep them working effectively. Sediment should be removed if it has reached one-half of the designed capacity for sediment storage.

The use of vegetation for erosion control purposes also requires a regularly scheduled maintenance program to repair seeded, sodded or other vegetated areas where the desired degree of stabilization has not been achieved. All seeded areas should be checked for plant emergence and density two to six weeks after planting. Spring plantings should be inspected again during the summer or early fall so reseeding can be performed as necessary during the fall planting season.

The SWPPP inspection and maintenance section should also describe who is responsible for inspections and maintenance of all post-construction BMPs after the land disturbance permit coverage is terminated and the permanent devices are functioning as operational water quantity and quality control devices. After the project is complete, proper stabilization has been achieved according to the general permit and inspection and maintenance of permanent practices have been properly passed off to responsible parties, the project closure should include a termination of coverage of the land disturbance permit using *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 for Missouri Department of Natural Resources (see Chapter 1: Permit Coverage Application Forms and Fees).

Making the SWPPP Work

Even the best SWPPP cannot cover the specifics of each situation that will arise on a construction site during the life of a project. It is the contractor's or site operator's responsibility to make sure the site complies with the goals and intent of the SWPPP at all times.
The SWPPP should show the practices to be in place at the start of construction as well as when the site design is at full build out.

The Missouri Department of Natural Resources Land Disturbance general permit states that the permittee must amend and update the SWPPP as appropriate during the term of the land disturbance activity. The SWPPP should record all land disturbance activities from the beginning of construction to the end with the date of occurrence. This would include the installation of best management practices and their removal or conversion into permanent post-construction stormwater control measures. This can be accomplished by a site activity log or notes on the site maps or a combination of both.

The site map should reflect the current activities at the site at any time throughout the construction project. The first records on the site map should include the installation locations and dates of the perimeter BMPs prior to clearing and grading and the location of the trailer, laydown and parking areas. The clearing and grading areas with appropriate dates should then be recorded. As work progresses additional notes should be made for cut areas, fill areas, utility installation, pouring footings and building pad, areas of temporary and final stabilization, etc. The last records on the site map should include the dates when temporary BMPs were removed and those areas stabilized. The last piece of record keeping at the very end of the project is for the permittee to sign and submit *Form H - Request for Termination of a General Permit*, Form--MO 780-1409, which will terminate coverage under the general permit. The site must be fully stabilized and all temporary BMPs removed.

The SWPPP is now complete and must kept in the records for three years from the date the Form H was submitted to the Missouri Department of Natural Resources. Submittal of *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 is often overlooked, but is an important requirement of the permit. If coverage under the general permit is not terminated, the permittee could continue to be held accountable for activities presumably associated with the permit.

Design Do's and Don'ts

The erosion and sediment control industry is constantly evolving to meet the demands of heightened public awareness of erosion and sediment control issues and regulatory requirements. In the 1970's, ponds were used as sediment basins, geotextiles as silt fence, straw bales as sediment barriers and rock as construction exit pads. Best management practices have evolved significantly since 1992 with the Phase I and II NPDES requirements. There has been extensive research on many of the devices mentioned in this guide, as well as newer products and devices. Designing an up-to-date SWPPP may be challenging because information and technology is constantly changing. Following are three long-standing design practices for which the method of implementation has evolved and where confusion might still exist while planning the use of the BMPs on a construction project.

Straw Bales

Straw bales have been proven to be very ineffective for sediment control. They are difficult to install correctly and do not last very long. EPA does not support the use of straw bales as an effective control for sediment on a construction site. They should never be used in concentrated flow channels as check dams or as inlet protection. If used at all they may be effective if installed properly on very flat, small areas where erosion control for the soils is also incorporated over the area.

Silt Fence

Silt fence is another device that should never be used in concentrated flow channels or as an inlet protection device. Remember when using silt fence as a sediment control device, there is the potential during heavy storm events where several feet of stormwater flow may pond behind the device causing flooding of the area. This can create significant damage and cause the device to fail.

Another misuse of silt fence is in the area of perimeter control. One requirement of the construction general permit is to maintain perimeter control. Controls must be in place along the perimeter where stormwater flow exits the permitted area, not the entire perimeter. Silt fence should only be placed along the contour and not up and down slopes, at the top of the hill or any other area that does not directly discharge stormwater flows. When silt fence is not

placed directly on the contour, the storm flow will follow the fence as it travels downhill, picking up volume and velocity. This will increase the chances of a blow out at the lowest point due to the increase of concentrated flow to the area. As a SWPPP designer, remember that sediment control devices slow the flow and pond the water and should not cause flooding. Silt fence has the capability to pond two or three feet of water and sediment behind it, and damage from flooding could occur.

Short Circuiting

The discharge point of the pond should not be located near the point where sediment laden stormwater enters the pond. Ponded water is a great energy dissipation device for sediment control (as long as it does not cause flooding). When sediment laden stormwater enters ponded water, the ponded water acts as an energy dissipater and the heavier sediment particles settle out at the entrance to the pond. With additional time the lighter particles in suspension will also settle out to the bottom of the pond. For this reason the discharge point of the pond should not be located near the point where sediment laden stormwater enters the pond. If the inlet is close to the outlet particles may not have sufficient time to settle to the bottom before being discharged, creating a condition called “short circuiting”.

The longer the traveling time for the water between the inflow and outflow the better the pond will function as a control device. If the pond is short circuiting because the inflow and outflow are too close together, it will not function well as a sediment control device. If due to space and topography, there is no way to design for the inflow into the pond to be as far away as possible to the outflow then design for a baffle wall or weir to be built between the two pipes so the entire pond is used as a control device.

Additional Resources

A Builder’s Guide to Low Impact Development –National Association of Home Builders Research Center www.lowimpactdevelopment.org/lid%20articles/Builder_LID.pdf

Examples of Green Infrastructure and Design Approaches – EPA
cfpub.epa.gov/npdes/greeninfrastructure/technology.cfm

Green Infrastructure Center
www.greeninfrastructurecenter.org

Low Impact Development Center
www.lowimpactdevelopment.org/

Low Impact Development for Stormwater Management – Toolbase Services
www.toolbase.org/Technology-Inventory/Sitework/low-impact-development

Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices
www.epa.gov/owow/nps/lid/costs07/

CHAPTER 5
INSPECTION FOR EROSION, SEDIMENT AND STORMWATER CONTROL

The Inspection

On-site inspections are necessary on a regular basis and after rain events to assure the proper functioning of soil erosion, sedimentation and stormwater control measures. Missouri Department of Natural Resources and certain local governments require the permittee or a representative of the permittee to conduct regular inspections every seven calendar days and within 48 hours of a rainfall event resulting in runoff from the site. The inspections shall be conducted by a person responsible for environmental matters at the site or a person trained and directly supervised by the person responsible for environmental matters at the site.

It is recommended the inspector be certified or properly trained. See training and certification information provided at the end of Chapter One in this document. If the site is also under an MS4 permit program, refer to the local inspection requirements and make sure they are also met. For a current list of regulated MS4s, visit www.dnr.mo.gov/env/wpp/stormwater/sw-phaseii-communities.pdf

All inspections should be documented by written reports, logs or checklist sheets. These reports should contain:

- The inspector's name and qualifications.
- Date and time of inspections.
- Dates when grading the site or phase of the site began.
- Comments concerning the success of each practice.
- What corrective action may be needed.
- A list of areas where land disturbance operations have permanently or temporarily stopped.
- Any verbal communications that took place as a result of the inspection.

The inspection report shall be signed by the person designated in the SWPPP to conduct the inspections. An example of an inspection report is provided at the end of this chapter.

Site inspectors need to be knowledgeable in erosion, sediment and stormwater control principles and the installation, function and maintenance of such practices. If additional training is needed, then Missouri Department of Natural Resources' regional office, the local Soil and Water Conservation District USDA, Natural Resources Conservation Service office, or local government planning or engineering departments may be able to provide technical assistance. Also refer to the training and certification information provided at the end of Chapter 1.

The inspector should have a copy of the SWPPP with drawings and specifications for all practices. This should include information on the amount of allowable sediment accumulation, design cross-sections, freeboard requirements and location of spoil areas.

The inspector may want to review the example inspection form before inspecting the site. Care should be taken to inspect all aspects of compliance with the state land disturbance permit as well as any local requirements that apply to the site. This includes all paperwork, updates and maintenance of the SWPPP or erosion and sediment control documents, public posting signage and BMPs. When listing the BMPs that are to be inspected, the inspector should include the good housekeeping practices required for trash dumpsters, designated concrete washout areas, portable toilets, petroleum and other chemical storage areas, etc.

After the inspection is complete and all deficiencies are noted on the inspection report, the inspector should document and communicate his/her findings to those responsible for each deficient BMP, explain what needs to be remedied, identify where it is located and determine a deadline for the correction. The inspector will also need to use, or provide the information necessary, in updating the SWPPP and site map on any changes that have occurred on the site since the last inspection. Most importantly, whenever an inspection notes a deficiency, the inspector should verify during the next inspection that corrections were made, and note when each previously noted deficiency was repaired.

Any deficiency noted on an inspection report must have a subsequent report which indicates that each deficiency was repaired or fixed within seven calendar days as required in the Missouri DNR and/or local land disturbance permit.

The inspector should refer to the details in the SWPPP and Section 6 of this guide to evaluate BMPs for correct installation, assess whether they are functioning effectively and determine how to remedy deficiencies in the implementation of the SWPPP. The inspector should consult with the SWPPP designer to resolve observed chronic erosion or sediment issues and let the designer know about observed ineffectiveness of any hydrologic control measures such as drainage channels or swales, check dams, ponds, culverts, etc.

Regulatory Inspections

Regulatory inspectors from EPA, Missouri Department of Natural Resources or a local agency may visit a construction site that has obtained permit coverage through their respective land disturbance permit program. The regulatory inspectors are authorized to inspect the permitted site for compliance with their regulatory program. A regulatory inspection report may include any of the following information:

- The inspector's name and the agency they represent.
- Who is accompanying the inspector on the site evaluation including other regulating agency or construction site personnel.
- Notes on deficient or missing paperwork or SWPPP requirements.
- Notes on BMP deficiencies including missing controls identified in the SWPPP, those requiring maintenance, or those that appear to be ineffective in erosion and sediment control.
- Notes on any other concerns or insufficient implementation of elements required under their stormwater permit program.
- Photo documentation.

The construction personnel may obtain helpful information and education from the Missouri Department of Natural Resources to assist in performing in a compliant manner. The department may provide guides and manuals available to assist the construction personnel identifying options for achieving the best results at the site.

The permittee may also receive advice from the department on ways to enhance the use of erosion control techniques as outlined in the SWPPP designed for the site. If the SWPPP is inadequate or practices prove to be ineffective, the inspector should advise the permittee to upgrade the SWPPP to incorporate other best management practices such as those found in documents referenced in the Missouri Department of Natural Resources' land disturbance permit. If appropriate, the inspector may provide a list of alternative BMPs to consider when pursuing correction. The regulatory inspector should avoid prescribing specific practices.

Example Inspection Scenarios

Figure 5.1 Grass Planted on a Cut Slope. Source: *ASP Enterprises, Inc.*

This cut slope was planted with fescue. In this example, there are clumps of grass with erosion between the clumps. A notation of "Insufficient vegetation" in the inspection report would identify the unacceptable condition , but does ot completely explain what is needed to correct the problem. Just reseeding this area will not fix the erosion occurring on the slope. The inspector needs to look to the root of the problem. There is no erosion control protecting the slope and seed. Seeding the slope and protecting with an erosion control blanket or sod might be appropriate for this slope. Minor regrading may be necessary to remove existing rills. Vegetation does not provide effective erosion control until it is fully established with a uniform density of at least 70 percent. Another revegetation problem identified in this image is the presence of hard packed gray subsoil instead of good topsoil. This is a common problem on many cut slopes. The inspector may want to note on their report to test the soil for percent organic matter and its cation exchange capacity to ensure the soil can sustain vegetative growth. In lieu of correcting any topsoil deficiencies and reseeding, the contractor may be able to achieve effective erosion control on low to moderate slopes by covering the area with mulch.

This inlet protection device has been damaged and is in need of repair. A notation in the inspection report such as “repair inlet”, does not identify the source of the problem. The inlet was damaged by an uninformed contractor so the root of the problem is education and communication with the contractors at the site. Education about the importance of the devices and an understanding of the shared liability when non-compliance issues arise would help deter damage to the devices. It would at least increase the chance that the device would be repaired immediately.

Figure 5.2 Broken Inlet Protection. Source: ABC’s of BMP’s

Here is an inlet device that was properly installed. So what is the problem? Remember that inlet devices are designed to block the flow of stormwater from entering the storm sewer system. They will pond the flow, dissipate the energy, settle out the sediments and allow the cleaner stormwater to leave the site. This is good, however, the silt fence has a low porosity and during a heavy rain event may pond up to two feet of water around the inlet. If that happens at this location it will create flooding in the street because the device is located at an intersection. The problem with the implementation of this BMP has nothing to do with installation and maintenance but rather the choice of control devices. With additional erosion control and soil stabilization around the inlet, especially in the roadside ditch or swale to the inlet, the contractor could remove the silt fence and only block the lower half of the inlet with a wattle type product. There are many control choices when it comes to inlet protection but the contractor should think about the consequences of the device chosen. When the flow through an inlet is restricted, more ponding will occur resulting in better sediment removal but at greater risk of the possible flooding. Conversely, a device that ponds less stormwater, but provides less treatment of the stormwater prior to discharge and increases the risk of releasing sediment off-site.

Figure 5.3 Inlet Protection Results and Consequences Source: ABC’s of BMP’s, LLC

Stormwater Construction Site Inspection Report

As an inspector it is critical to understand not only the deficiency but also what caused it so the problem can be corrected. The following examples will look at deficiencies and what needs to be done to correct them.

General Information		
Project Name		
Permit Tracking No.		
Date of Inspection		
Inspector's Name(s)		
Inspector's Title(s)		
Inspector's Contact Information		
Inspector's Qualifications[1]		
Describe present phase of construction		
Type of Inspection: ☐ Routine ☐ Pre-storm event ☐ During storm event ☐ Post-storm event		
Weather Information		
Has there been a storm event since the last inspection? ☐ Yes ☐ No If yes, provide: Storm Start Date & Time: Duration (hrs): Approximate Amount of Precipitation (in):		
Weather at time of this inspection? ☐ Clear ☐ Cloudy ☐ Rain ☐ Sleet ☐ Fog ☐ Snow ☐ High Winds ☐ Other: Temperature:		
Discharge Information		
Have any storm water discharges occurred since the last inspection? ☐ Yes ☐ No If yes, describe:		
Are there any storm water discharges occurring at the time of inspection? ☐ Yes ☐ No If yes, describe:		

Documentation

On-Site Documentation			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Is the SWPPP on-site and up-to-date?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the SWPPPP properly signed and certified?	☐ Yes ☐ No	☐ Yes ☐ No	
Is a copy of the LD permit available at the site?	☐ Yes ☐ No	☐ Yes ☐ No	
Is a copy of the signed permit authorization or coverage available on site?	☐ Yes ☐ No	☐ Yes ☐ No	
Are all applicable documents available and readable on the public posting sign near the entrance of the site?	☐ Yes ☐ No	☐ Yes ☐ No	
Are the clearing, grading or excavating activities recorded and kept with the storm water plan?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the SWPPP site map, being updated with dates and locations of grading activity and locations of port-a-potties, trash dumpsters, stockpiles, fuel tanks, etc.?	☐ Yes ☐ No	☐ Yes ☐ No	
Have all BMPs action items, identified in the last inspection report, been addressed?	☐ Yes ☐ No	☐ Yes ☐ No	

Structural Controls

Silt Fence or Other Perimeter Type Device			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Properly installed (tied, trenched and jointed correctly)?	☐ Yes ☐ No	☐ Yes ☐ No	
Stakes installed correctly and properly spaced?	☐ Yes ☐ No	☐ Yes ☐ No	
Is maintenance or repair required? (holes, tears, fabric off stakes, fence down or removed, etc.)	☐ Yes ☐ No	☐ Yes ☐ No	
Does the accumulated sediment exceed the level allowed in the permit?	☐ Yes ☐ No	☐ Yes ☐ No	
Is silt fence receiving concentrated flows? If yes, alternate BMP proposed?	☐ Yes ☐ No	☐ Yes ☐ No	

Wattles			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Properly installed by being trenched and jointed correctly?	☐ Yes ☐ No	☐ Yes ☐ No	
Stakes installed correctly and properly spaced?	☐ Yes ☐ No	☐ Yes ☐ No	
Is maintenance or repair required?	☐ Yes ☐ No	☐ Yes ☐ No	
Does the accumulated sediment exceed the level allowed in the permit?	☐ Yes ☐ No	☐ Yes ☐ No	

Structural Controls

Diversion/Swale/Channel Conveyance

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Properly stabilized with erosion control blanket, turf reinforcement mat, or vegetation?	☐ Yes ☐ No	☐ Yes ☐ No	
Velocity of flow through channel is not causing erosion or scour? If scour or erosion due to high velocity, consult designer.	☐ Yes ☐ No	☐ Yes ☐ No	
Is maintenance or repair required?	☐ Yes ☐ No	☐ Yes ☐ No	

Check Dam

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Installed, spaced and operating properly? (no cutting around edges or scour due to high velocity)	☐ Yes ☐ No	☐ Yes ☐ No	
Is maintenance or repair required?	☐ Yes ☐ No	☐ Yes ☐ No	
Does the accumulated sediment exceed the level allowed in the permit?	☐ Yes ☐ No	☐ Yes ☐ No	

Storm Drain Inlet

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Selected, installed and maintained correctly? Identify storm drains that require cleaning or maintenance.	☐ Yes ☐ No	☐ Yes ☐ No	
Is the device creating a flooding situation during rain events? Consider alternative solutions.	☐ Yes ☐ No	☐ Yes ☐ No	

Sedimentation Pond or Trap

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Are ponds located and built according to the SWPPP?	☐ Yes ☐ No	☐ Yes ☐ No	
Are the banks of the pond stabilized?	☐ Yes ☐ No	☐ Yes ☐ No	
Is accumulated sedimentation below the max level allowed in the permit?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the overflow structure installed per design?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there evidence of sediment discharge?	☐ Yes ☐ No	☐ Yes ☐ No	

Energy Dissipation Outlet From Pipe, Pond, Trap or Dewatering

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Properly installed and working correctly with no visible scour or erosion?	☐ Yes ☐ No	☐ Yes ☐ No	
Has rock been dislocated downstream?	☐ Yes ☐ No	☐ Yes ☐ No	

Active Treatment System			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Is there sufficient polymer material?	☐ Yes ☐ No	☐ Yes ☐ No	
Do deposited sediments need to be removed?	☐ Yes ☐ No	☐ Yes ☐ No	

Pipe Slope Drain			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Properly installed according to the plan?	☐ Yes ☐ No	☐ Yes ☐ No	
Working correctly?	☐ Yes ☐ No	☐ Yes ☐ No	
Is maintenance or repair required?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there any scour or piping at top, around or at discharge of the pipe?	☐ Yes ☐ No	☐ Yes ☐ No	

Soil Stabilization

Buffer Requirements			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Are any buffer zones required by the SWPPP being preserved?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the vegetation healthy, dense and effective?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there sediment deposition within the buffer zone?	☐ Yes ☐ No	☐ Yes ☐ No	

Temporary Stabilization			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Has temporary stabilization been completed within timeframe specified in the permit?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the vegetation established sufficiently to reduce or eliminate erosion?	☐ Yes ☐ No	☐ Yes ☐ No	
Are the stabilized banks, stockpiles and borrow areas on/offsite being maintained and/or repaired?	☐ Yes ☐ No	☐ Yes ☐ No	
Has temporary seeding been mulched or otherwise protected?	☐ Yes ☐ No	☐ Yes ☐ No	

Temporary Stabilization			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Has temporary stabilization been completed within timeframe specified in the permit?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the vegetation established sufficiently to reduce or eliminate erosion?	☐ Yes ☐ No	☐ Yes ☐ No	
Are the stabilized banks, stockpiles and borrow areas on/offsite being maintained and/or repaired?	☐ Yes ☐ No	☐ Yes ☐ No	
Has temporary seeding been mulched or otherwise protected?	☐ Yes ☐ No	☐ Yes ☐ No	

Rolled Erosion Control Devices			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Is the device installed correctly with proper over-lap, toed in, and staples?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the device laid on a smooth soil surface with no clods or tenting?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there evidence of soil movement below the device?	☐ Yes ☐ No	☐ Yes ☐ No	
Has the device been moved, torn out or become dislodged?	☐ Yes ☐ No	☐ Yes ☐ No	

Mulch or Compost			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Is the soil completely covered and protected?	☐ Yes ☐ No	☐ Yes ☐ No	
Has the product been moved or displaced by the storm water flow?	☐ Yes ☐ No	☐ Yes ☐ No	

Pollution Prevention

Concrete Washout			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Located according to the SWPPP and location shown on site map?	☐ Yes ☐ No	☐ Yes ☐ No	
Built according to SWPPP?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the washed concrete being contained and area maintained?	☐ Yes ☐ No	☐ Yes ☐ No	
Is the washout pit or device full and in need of clean out?	☐ Yes ☐ No	☐ Yes ☐ No	

Stabilized Construction Exit			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Is there evidence of off-site tracking?	☐ Yes ☐ No	☐ Yes ☐ No	
Built according to SWPPP?	☐ Yes ☐ No	☐ Yes ☐ No	
Is maintenance or repair required?	☐ Yes ☐ No	☐ Yes ☐ No	
Wash water properly contained, treated and disposed of?	☐ Yes ☐ No	☐ Yes ☐ No	

Good Housekeeping and Waste Disposal Practices

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Are fuels and other chemicals being properly stored and contained?	☐ Yes ☐ No	☐ Yes ☐ No	
Material storage BMPs functioning correctly?	☐ Yes ☐ No	☐ Yes ☐ No	
Trash and debris cleaned up, stored in appropriate containers and disposed of properly when removed from site?	☐ Yes ☐ No	☐ Yes ☐ No	
Porta-potties or other sanitary waste receptacles properly managed?	☐ Yes ☐ No	☐ Yes ☐ No	
Is mason's area properly maintained?	☐ Yes ☐ No	☐ Yes ☐ No	
Paint wash properly managed?	☐ Yes ☐ No	☐ Yes ☐ No	
Truck and other equipment fueling area properly managed?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there any evidence of or have there been any spills of petroleum or hazardous waste?	☐ Yes ☐ No	☐ Yes ☐ No	
If so, is the spill at or above the reportable quantity noted in the SWPPP?	☐ Yes ☐ No	☐ Yes ☐ No	
Is dust control being performed according to SWPPP?	☐ Yes ☐ No	☐ Yes ☐ No	

Stormwater Discharge Evaluation

Off-site Accumulation of Sediment or Any Non-Storm Water Discharges

BMP/activity	Implemented?	Required Maintenance	Corrective Action Needed and Notes
Is there evidence of sediment in storm water discharge?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there evidence of sediment in the waters downstream from the construction site?	☐ Yes ☐ No	☐ Yes ☐ No	
Are the number and location of outfalls consistent with the SWPPP? Update SWPPP as needed.	☐ Yes ☐ No	☐ Yes ☐ No	
Are velocity dissipation devices at discharge locations preventing erosion of stream banks and receiving waters?	☐ Yes ☐ No	☐ Yes ☐ No	

Checklist for Terminating Permit Coverage

Termination Requirements			
BMP/activity	**Implemented?**	**Required Maintenance**	**Corrective Action Needed and Notes**
Is site stabilized in accordance with the SWPPP and LD permit?	☐ Yes ☐ No	☐ Yes ☐ No	
Has 70 percent density of vegetative cover been achieved?	☐ Yes ☐ No	☐ Yes ☐ No	
Is there any evidence of erosion?	☐ Yes ☐ No	☐ Yes ☐ No	
Have temporary erosion control measures been removed and that area stabilized?	☐ Yes ☐ No	☐ Yes ☐ No	
Have permanent ponds been cleaned of sediment accumulation and sediment properly disposed of?	☐ Yes ☐ No	☐ Yes ☐ No	
Have all fuel and waste containers been removed and/or properly disposed of?	☐ Yes ☐ No	☐ Yes ☐ No	

Inspection Report certification Statement

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Print name and title:____

Signature____________________________________Date:________________

CHAPTER 6
INSTALLATION AND MAINTENANCE OF BEST MANAGEMENT PRACTICES

Introduction

Changes made to the land during construction have far reaching effects, both on and off the construction site. Contractors can make important contributions to protecting water quality by installing the appropriate practices. Because of the many potential effects on the local ecosystem, the services of qualified engineering, design and environmental professionals are necessary in the land grading and construction activities associated with developing a site.

This chapter describes practices to help prevent or minimize erosion and sediment movement and pollutant discharge from a construction site. Remember also that pollutants can move through the soil on the construction site, enter shallow groundwater directly and contaminate drinking water supplies. This can be prevented by cleaning up the site before construction begins and by preventing pollutants from entering the site.

Use of Sections in This Chapter

This chapter provides general information on practices and controls. (For more detailed BMP design criteria, refer to the design manuals listed below.) This chapter is organized in sections by the type of controls and the practice or the function they provide.

The first section is Site Preparation, it covers practices and procedures that should be operational prior to land clearing and grading, such as construction exit pads and wheel wash structures as well as practices to install as topsoil is removed and grading begins.

The second section, titled Pollution Prevention and Good Housekeeping, includes those types of devices and site prctices employed to reduce or eliminate pollutants other than sediment from discharging from the construction site. This would include solid waste, sanitary waste, petroleum or hazardous waste, concrete wash water and other pollutants.

The third section discusses surface stabilization or erosion control techniques that are necessary as soon as possible following land disturbing activities. Most erosion control devices work by dissipating the energy in the raindrop to reduce the potential for soil to be dislodged during a storm event. However, there are a wide range of surface stabilization options available depending on the function they need to perform.

Remember that erosion controls are preventive measures to keep soil in place, whereas sediment control devices are remediation measures for sediment that is moving with the stormwater flow.

Section four discusses runoff or sediment controls. These types of controls work primarily by slowing the flow and ponding the stormwater. This dissipates the energy in the flowing water so suspended sediment can settle out of the water and not leave the construction site. This results in treated or cleaner stormwater leaving the site.

Section five of this chapter includes any practice installed during construction that is designed as a permanent feature to control the stormwater discharge for quantity and/or quality once the site is fully stabilized and operational (post construction stormwater control). These permanent devices are built during the construction phase of the project but are not typically put into use until after construction is complete and the site is stabilized. Today's stormwater management goals require permanent practices that control stormwater quality as well as quantity. The site manager or job foreman should be aware of all planned post-construction measures designed for this purpose.

The site superintendent can refer to Section 5 of this chapter for a better understanding of permanent water quality devices shown on site plans, in addition to understanding placement of stream buffers and the placement of stormwater control measures. To differentiate from temporary (during construction) controls, permanent/post construction controls will be referred to as Stormwater Control Measures, or SCMs, and not BMPs which refer to temporary controls. This section will also discuss how to retro-fit controls from use as a sediment control during construction to a post-construction operational or SCM control. This discussion will include timing of the construction and functioning of these types of control devices.

Each section in this chapter has an index tab, so that finding the practice is easier. To help the contractor, site manager, job foreman or inspector, each section is broken into the following six basic components.

Practice Description

Defines the practice, describes where and for what it is used, and may include other basic information.

Recommended Minimum Requirements

Gives some suggested specifications or requirements for the practices that should be respected as minimums. However, this is only a guide and any required design standards should be followed. This part also suggests either a qualified or registered design professional (see Glossary) be the designer of the practice. Note: Site specific designs for the watershed, topography and soils may dictate more restrictive requirements.

Construction Installation

Gives step-by-step proce¬dures for installing the practices, with a construction verification checklist at the end. For some practices, several options are given. (e.g., Soil Bioengineering for Slope Protection covers nine different practices).

Maintenance, Inspection and Removal

Designed to help the site manager or a designated employee ensure that needed inspections and maintenance activities are completed.

Common Problems and Solutions

Lists problems that are often found on sites and recommendations for solutions. Many of the common problems can be avoided by using the recommended minimum requirements and following the construction sequence. This tips can also be used to troubleshoot problems and when the design professional may need to be contacted.

Design Manual References

Reference manuals to be followed for design plans and specifications include but are not limited to the following:

Georgia Stormwater Management Manual, Atlanta Regional Commission, August 2001. www.georgiastormwater.com/

Kansas City APWA Standards and Specifications BMP Manual kcmetro.apwa.net/chapters/kcmetro/specifications.asp

Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers SEMCOG 2008 www.semcog.org/lowimpactdevelopmentreference.aspx

Manual of Best Management Practices for Stormwater Quality March 2008, Mid America Regional Council. kcmetro.apwa.net/chapters/kcmetro/specs/APWA_BMP_Manual_Mar08.pdf

Maryland Stormwater Design Manual, Volumes I & II, Maryland Department of the Environment, 2000. 2009 Revised. Maryland Department of the Environment, Baltimore, MD. www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp.

Springfield Storm Drainage Criteria Manual draft 2007. Wright Water Engineers,. www.springfieldmo.gov/stormwater/developer.html

The Minnesota Stormwater Manual, Version 2 November 2005, Minnesota Pollution Control Agency, http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

SECTION 1: SITE PREPARATION

Before construction begins, the construction manager, site superintendent or job foreman should meet with the design professionals and be supplied with a complete SWPPP or Erosion, Sediment and Stormwater Control Plan including a narrative description of the site and environmental conditions, detailed site map, construction/grading schedule, seeding schedule and maintenance/inspection schedule.

The construction manager, site superintendent or job foreman should review all federal, state and local regulations and understand completely the consequences of violations including but not limited to fines and imprisonment. Invite a local Missouri Department of Natural Resources representative to a preconstruction meeting if there are questions regarding the regulations. Invite all land disturbing contractors to the meeting.

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Caution should be given to placing BMPs near streets. The drainage patterns in the vicinity of and around streets in new developments should be carefully studied so that the design or construction of BMPs will both meet local requirements and prevent any major flooding, sediment accumulation, traffic interruptions, o or rad damage during significant storm (design) events.

Post-construction practices today do not mean what they did in the 1970s when it was mostly about water quantity. Refer to Section 5 of this chapter for a complete discussion about post-construction measures that address both quantity and quality. The site manager or job foreman should also be aware of all planned post-construction measures. Many of today's state-of-the-practice post-construction features such as rain gardens, infiltration trenches and bioswales are incorporated into the initial site design. Their ultimate placement and function need to be considered throughout the construction phase in order to avoid roadblocks to implementation. See Section 5 for more detail.

For more information on environmental site design for the development plan and operation and maintenance considerations, see *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011*.

Temporary Rock Construction Exit Pad

Figure 6.1 A temporary rock construction exit can reduce sediment and resulting safety hazards on public streets. This pad needs maintenance due to sediment filling the void spaces between the rocks making the rock exit pad ineffective. Source: ABC's of BMP's, LLC

Practice Description

A temporary rock construction exit is a stone base installed to provide an exit area where construction vehicles can drop the mud and caked soil from their tires to avoid transporting it onto public roads. The mud and dirt that ends up on the street is called “track out” and is the number one complaint associated with construction projects. The rock will jar and flex the tire treads so dirt and mud on the tires will become dislodged and collect in the voids of the rock exit pad. This device should be incorporated anywhere traffic will be leaving a construction site and moving directly onto a public road or other paved area.

The rock exit pad is often not effective by itself and requires a lot of maintenance. High-clay content soils may not adequately separate from the tires, and the rocks must be reconditioned as void space is filled with sediment. You may need to install additional practices, some of which are described below. Superior practices may be available in the construction industry, although the temporary rock construction exit pad is most commonly used.

Prior to the start of construction, temporary rock construction exit pads should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throught the construction process.

The design professional should give consideration to the following:

- Limit the points of entrance and exit to the site.
- Designate combination or single purpose access points to the construction site, and require all employees, subcontractors and others to use them.
- Properly grade each construction entrance and exit to prevent runoff from leaving the construction site.
- Route runoff from a stabilized pad through a sediment-trapping device before discharge.
- Design the pad to support the heaviest vehicles and equipment that will use it.
- Avoid placing the exit pad in low areas where stormwater accumulates or discharges off-site.

Recommended Minimum Requirements

Aggregate Size

2- to 3-inch washed stone.

Pad Design

- Thickness: 6 inches minimum.
- Width: 12 feet minimum or full width of roadway, whichever is greater.
- Length: 50 feet minimum.

Signage

Clearly designate these areas to be used for exiting the construction site and make sure everyone involved with the project is aware that track out is not tolerated.

Wheel Wash (Optional)

Level the area with a minimum of 3 inches of washed stone. Remember if a wheel wash station is installed, all wash water must be collected and treated before it is discharged from the construction site. A simple sediment trap can be added next to the rock pad to collect the wash water and allow it to discharge over a check dam and into the road ditch. See additional information on wheel wash devices later in this section.

Geotextile Fabric

An underliner of woven geotextile (fabric) should be used under the rock to provide stability.

Construction

Avoid locating on steep slopes or at curves on public roads. If possible, locate where permanent roads will eventually be constructed. Limit the number of access roads to limit the inspection and maintenance of these devices and areas where sediment could be tracked onto public roads.

Site Preparation

Remove all vegetation and other unsuitable material from the foundation area; grade and crown for positive drainage. If wheel washing is indicated, provide a sediment trap adjacent to the rock pad to collect the discharged wash water for treatment before it is released off-site.

Grading

- If the slope towards the road exceeds 2 percent, construct a 6- to 8-inch high ridge with 3:1 side slopes across the foundation approximately 15 feet from the entrance to divert runoff away from the public road.
- Place geotextile filter fabric on the graded foundation to improve stability.

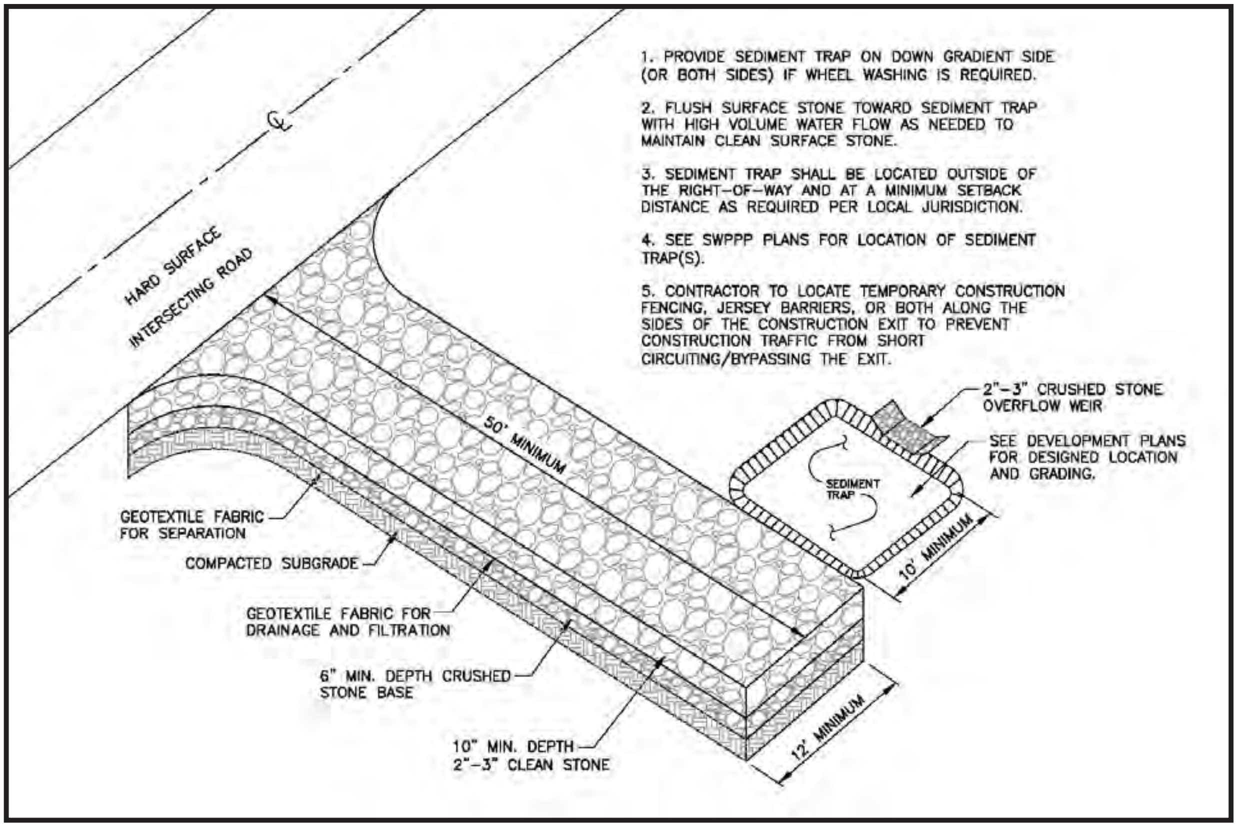


Figure 6.2 Typical Temporary Rock Construction Exit. Source; BFA Inc.

- Place stone to dimensions and grade shown on plans. Stone size should not be less than 2 inches or greater than 3 inches. Stones in the dimensions of 4- to 6-inches may become trapped between the dual tires on some construction vehicles and be transported off-site to later be thrown from the trucks tires and cause damage to vehicles or their drivers. Leave the surface smooth and sloped for drainage.
- Divert all surface runoff and drainage from the stone pad to a sediment trap or basin.

Maintenance, Inspection and Removal

- Inspect stone pad and sediment disposal areas weekly and after storm events or heavy use. When the voids between stones are filled with sediment or the pad becomes smooth and does not function to jar the truck and flex the rubber, it is not functioning properly and should be repaired. Add more rock or turn the existing stone over to move sediment below the stone so the stone pad will again have proper roughness and void spaces.
- Reshape pad as needed for drainage and runoff control.
- Topdress with clean 2- to 3-inch stone as needed.
- Immediately remove mud or sediment tracked or washed onto public road within 24 hours.
- Keep all temporary roadway ditches clear.
- Repair any broken road pavement immediately.
- Remove this temporary device and stabilize the site stabilized prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Inadequate runoff control; sediment washes onto public road.	Install diversions or other runoff control measures.
Stone too small, pad too thin or geotextile fabric absent; results in ruts and muddy conditions as stone is pressed into soil.	Increase stone size or pad thickness, or add geotextile fabric. Stone should not be more than 4-inches in diameter, to avoid rocks being caught and thrown from dual tires.
Pad too short for heavy construction traffic.	Extend pad beyond the minimum 50-foot length as necessary.

Wheel Wash

Figure 6.3 Industrial wheel wash unit with self contained and recycled wash water. Source: *Innovative Equipment Solutions.*

Practice Description

A wheel wash device can consist of a range of tools from a simple compressor, hose and water source to a large scale industrial truck wash system. A wheel wash is designed to complement the rock construction exit pad to reduce the amount of sediment that might leave the construction site via construction vehicle traffic. Several portable wheel wash systems are available on the market today.

Recommended Minimum Requirements

While the installation of a wheel wash on the construction site will minimize mud tracking onto the roads, it is necessary to collect and treat the wash water to keep it from discharging off-site. Whatever type of wheel wash device is used at the construction site, a collection of the wash water is required in the form of a sediment trap or other such device. The water must be allowed to settle so the sediment is retained on-site and the treated water is allowed to discharge.

The size of the device and quantity of wash water will depend on the quantity and size of trucks treated. Some devices such as the one pictured above have self contained wash water collection systems that do not discharge the runoff.

Construction

Whether you install a portable wheel wash, or construct one on-site, you will need a water source and a collection system for the wash water. How the wheel wash is constructed and installed will depend on the type of system used. Make sure the installation of the system allows for a drip area between the device and public road so as little as possible of the wash water is transported to the public road to decrease wetting of the road. This is extremely important in cold weather when freezing is a possibility and the wash water could create hazardous conditions.

Maintenance, Inspection and Removal

- Capture all sediment from the wash water on-site and dispose of it in an appropriate manner.
- Clean out wash water capture device when sediment fills it to greater than 50 percent.
- Removal of this temporary device must be performed and the site stabilized prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One-Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Sediment laden water drops onto the public road from the trucks exiting the construction site.	Increase the amount of washing to remove sediment from truck and increase the distance from wash area to road to provide a drip/dry pad for trucks. This will reduce water getting onto the public road.
Sediment-laden wash water from the trucks leaving the site drips onto the public road creating slick conditions.	Increase the washing of the vehicle on the site and allow the truck to drip-dry before driving onto the public street. Provide a sediment trap for wheel wash run-off as necessary.
Temperatures are near or below freezing creating ice from the wash water.	Discontinue the use of water to remove sediment from the construction vehicles before they enter the public street.

Rumble Plate

Figure 6.4 Prefabricated rumble plate, which produces a vibration of the tires and vehicle to dislodge dirt and mud form the construction equipment. Source: *Track out Control, LLC*

Practice Description

A rumble plate is a device that provides rough vibration to construction vehicles exiting the construction site. The vibration dislodges dirt and mud from the tires and undercarriage of the vehicles so sediment does not leave the construction site and drop onto a public road.
The rumble plates can be constructed of many types of material including, but not limited to, pipe or wood poles.

Recommended Minimum Requirements

Size the plate for maximum efficiency and allow for void space and sediment collection under the plate. Create a width so construction vehicles can not drive around and avoid the device.

Construction

Many rumble plate devices are prefabricated and shipped by the manufacture to the construction site. To construct your own device, remember the objects you construct it with need to be different diameters and spacing to create the vibration effect. The size and spacing of material should not be such as to cause harm or destruction to the vehicles driving over it.

The device should sit up on a frame with a void space below so the sediment drops from the trucks is trapped under the device. Then you can lift the device and scrape out the dropped sediment for easy clean out. Dispose of the sediment in an appropriate manner.

Maintenance, Inspection and Removal

- Clean sediment from under the device when it is close to filling the void area underneath. Dispose of the sediment on the construction site in an area that is stabilized and protected with a sediment control device.
- Remove the temporary device and stabilize the site stabilized prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One-Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Device is ineffective.	Build the device longer and wider so construction vehicles can not exit without traveling over the device.
Device does not create a rough vibration.	Redesign the device with varied sizes of pipe and spaces between pipes.
After vehicles drive over the device, sediment is dropped onto the public street – device is not long enough to be effective or does not create a rough enough vibration.	Increase the length of device, clean out sediment from under the device and if necessary, redesign to increase vibration to vehicles driving over it.

Bamboo Mats

Figure 6.5 Bamboo mats placed at the exit of the construction site to contain dirt and mud falling from the construction vehicles before they exit the site. Source: *Brock White, LLC*

Practice Description

Bamboo mats are flexible fabric or mesh sewn together with pockets that hold bamboo reinforcing members. This alternative to rock construction exits is portable, reusable and can be joined with other mats to increase width and length as necessary. This device is not recommended for heavy truck traffic and should be considered for smaller construction projects only such as house lots or small construction sites. The bamboo can break down with excessive traffic from heavy construction equipment.

Recommended Minimum Requirements

Mats should be put together to meet design standards as well as state and local permit requirements. Mats can be effective until the reinforcing members break down. They are not designed for long periods of heavy use.

Construction

These mats are manufactured and shipped to the buyer to be installed on-site. They are reusable.

Maintenance, Inspection and Removal

- Inspect the mats weekly and after rain events.
- Clean sediment from mats and replace broken down mats as needed.
- Remove this temporary device and stabilze the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 of permit coverage (see Chapter One-Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Sediment fills area between reinforcing members.	Will need to be cleaned as necessary.
Reinforcing members may break down with extended heavy traffic.	Individual mats will need to be replaced if this occurs.

Streambank Setback

Figure 6.6: Homes too Close to Streambank Source: K. Grimes, SWCD, St. Charles County.

Practice Description

A streambank setback limits how close structures can be placed to the stream, and it restricts vegetation removal and grading of the riparian area along flowing waters. This practice is intended to protect the banks of natural streams from damage due to development, lessen the risk of flooding in developed areas and provide a buffer between the developed area and the stream. A properly maintained streambank setback will help maintain channel capacity and stability, reduce the sediment load in the channel and reduce the movement of pollutants into the stream. Setbacks help preserve natural channel meander and protect homes and other buildings from damage due to bank erosion and flooding.

The following recommended minimum requirements may not be adequate to protect water quality. Many communities have stream setback requirements up to 300 feet, depending on the quality of the stream to be protected. As a good example of a stream buffer ordinance, see the ordinance for the City of Kansas City or the City of Lenexa, Kansas at www.ci.lenexa.ks.us/LenexaCode/codetext.asp?section=004.001.015.

Streambank setbacks can also apply to areas adjacent to excavated open channels used for site drainage, drainage ways and watercourses that route runoff to streams. Consult your local government for ordinance requirements.

Recommended Minimum Requirements

Prior to the start of construction, the 100-year floodplain established by the Federal Emergency Management Agency and the streambank setback area should be shown on the design plan prepared by a registered design professional. Plans should be referred to by the site superintendent, job foreman and field personnel throughout the construction process. The streambank setback should be established according to the planned alignment and grade. Vegetation should be inventoried and flagged for retention.

Channel

Ensure that the channel is stable before determining the width of streambank setback.

Streambank Setback in Developed Areas

The greater of the following is recommended:

- A minimum of 50 feet from the top of the streambanks (larger setbacks will be needed where channels are downcutting, hydrology is shifting and in large drainage areas - if sufficient land is available, a 100-foot setback is encouraged to protect the stream from degradation and to protect property) beyond the 100-year floodplain.

Vegetation

If possible, preserve desirable natural vegetation within the setback area, especially on steep slopes. Establish vegetation on all areas without sufficient cover (see Vegetative Protection in the Streambank Protection section). Overall fish and wildlife habitat requirements and landscape character should be considered in determining the scope of streambank setback.

Street Setback

Streets in new developments should be constructed so that they remain usable during runoff from the design storm or according to local requirements.

Water Surface Elevation

A minimum of 1 foot below the ground floor of private dwellings and commercial buildings in a new development during the 100-year frequency, 24-hour duration storm.

Permits

Contact the Corps of Engineers and local authorities for permit requirements; permits may be needed if placing fill in wetlands or streams.

Construction

Site Preparation

- Follow all federal, state and local regulations for channel improvements required to increase stream capacity (due to development).
- Open channel cross sections should not be reduced in order to increase streambank setback. The use of levees within small watersheds is discouraged.
- Locate all underground utilities.

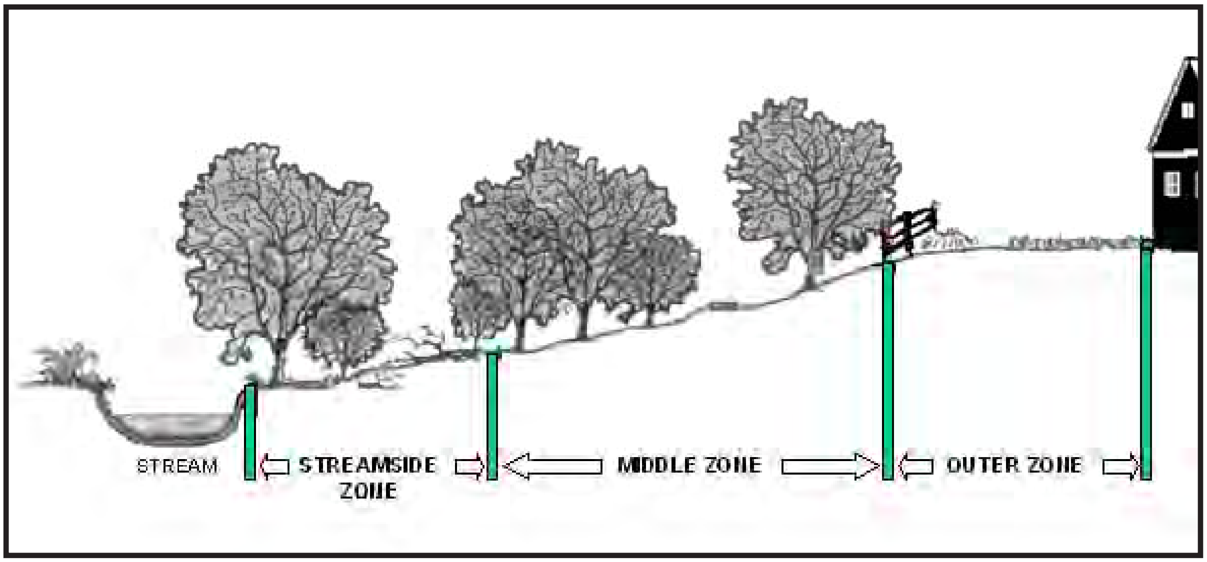


Figure 6.7 Three-Zone Stream Buffer System *Minnesota Stormwater Manual*. November 2005.
Source: Adapted from Schueler, 1995.

Natural Channels

- Natural channel side slopes should not be disturbed. When disturbance is necessary to develop a site, reestablish vegetation on channel side slopes as soon as possible after excavation or improvement.
- Consider the natural zones of a streambank community when placing vegetation. Use native plant materials for establishment and long term success. Lists of suitable species may be obtained from the Missouri Department of Conservation or NRCS.
(See Streambank Protection.)
- Existing woody vegetation adjacent to the stream should not be disturbed.
- Leave any right-of-ways in the best condition feasible, consistent with the project purposes and adjacent land uses. A permit will be required to work in the right-of-way from the governing authority.
- Preserve or plant adapted trees to provide shade to prevent thermal pollution in the stream, help stabilize banks and provide wildlife habitat in those areas of perennial flow or where woody cover exists.

Erosion Control

- Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete.
- Establish vegetation on all disturbed areas immediately after construction.
- The streambank setback area should not be used as a buffer strip during construction. This is important – if it is used as a sediment buffer, it could become contaminated with sediment and kill all the natural vegetation.
- Use temporary diversions to prevent lateral surface water from running onto the streambank setback area.
- After construction, if overland flow is required to go through the streambank setback area, velocities should be low (5 feet per second or less).

Safety

- At the completion of each day's work, move all construction equipment away from the streambank setback area in anticipation of flooding.
- Temporary stream crossings should be used by construction equipment to prevent destruction of the streambank setback areas.
- Construction materials and waste material should not be stored in the stream channel or streambank setback area.
- Provide temporary fencing and post warning signs until vegetation is established in areas that are disturbed.
- Provide site drainage.

Construction Verification

The alignment and width of the setback should be maintained during all construction activities. The final grades and elevations of the setback area should be checked to insure compliance with plans and specifications.

Maintenance, Inspection and Removal

- Check the streambank setback area after every storm event during the period of construction. In the setback area immediately adjacent to the stream (a minimum 10 foot width), reseed bare areas of soil greater than one square foot upon discovery and protect from soil erosion.
- Protect new plantings in the streambank setback area from livestock or wildlife.
- Mulch, spray (with an herbicide approved for aquatic use) or chop out undesirable vegetation periodically to prevent its growth.
- Keep inlets to side drainage structures open.
- Keep subsurface drain outlet pipes open and protected.
- Prohibit certain activities in the stream setback area, such as clearing and grading, drainage ditching, filling or dumping; and storage of motorized vehicles.
- Streambank setback vegetation maintenance after construction is the responsibility of the land owner. Make sure the landowner knows and understands their responsibility and the state and local requirements in their area.

Common Problems and Solutions

Problem	Solution
Variations in topography on site indicate setback or channel is inadequate or will not function as intended.	Changes in the plans may be needed.
Design specifications for seed variety, trees, mulch and fertilizer cannot be met.	Substitution may be required. Unapproved substitutions could result in additional flooding and erosion of the streambank.
Erosion of streambank setback; caused by disturbed land in setback area, inadequate vegetation or concentrated flow	Establish adequate vegetation in all areas or install measures to reduce flow concentrations.
Slumping failure or slides in streambank; caused by steep slopes.	Repair by excavating failed material and replacing with properly compacted fill. Consider reducing slope or installing streambank protection measures.
Reduction in stream capacity; caused by overgrowth of vegetation on the streambank.	Selectively cut overgrown vegetation.

Tree Protection

Practice Description

Tree protection preserves and protects trees during construction. Trees provide aesthetic and economic value, and aid in energy conservation, landscaping, air purification and erosion control. This practice applies to any construction site where desirable trees are present and need to be protected.

Trees can be damaged or killed by direct contact with construction equipment, compaction of the soil within the root zone of the tree, changes in the elevation of the water table due to site grading, and by construction chemicals and refuse. Although damage may be unseen, it can result in tree death within three or four years. Damage to the root zone is the leading factor in the unintentional destruction of trees.

Recommended Minimum Requirements

Prior to start of construction, desirable trees (including sensitive species) should be selected and marked for protection by a registered design professional. A grading plan that indicates the location of protected trees, utility trenches and other protected areas (e.g., floodplains, steep slopes, wetlands and streambanks) should be made available to field personnel. Areas for parking equipment should be designated away from the canopy (drip line) to protect the root zones of desired trees, shrubs, stream buffer vegetation and other protected areas. The root zone of plants is generally as broad as the drip line.

Temporary Fences

Placement

Around the dripline or tree canopy perimeter to restrict traffic, excavation, parking, storing materials and filling under the tree canopy. (For tree species sensitive to root damage, place the fence at the critical root radius to ensure tree's survival.)

Materials

Snow, board, plastic or cord fence.

Restricted Activities

Use temporary fence to restrict traffic, excavation, parking, storing materials and filling under the tree canopy (or at the critical root radius to ensure survival of sensitive species).

Permanent Drains

Install permanent drains in areas where site grading may be expected to cause water table saturation of the root zone (See Subsurface Drain).

Grading

Minimize cut and fill near trees by following the natural contours, and locating roadways, storage areas and parking pads away from desired tree stands.

Trenching

Minimize trenching near tree canopy perimeter and place several utilities in one trench when possible.

Up to 90 percent of trees' roots may be in the top 12 inches of soil. Typically, roots spread out from two to three times the width of the canopy or tree's branches.

Build a barrier at the dripline (or at the critical root radius for sensitive species) to prevent damage from soil compaction, cut and fill operations physical wounds.

To calculate the critical root radius: measure the tree's diameter in inches at breast height (4.5 feet above the ground), multiply that number by 1.5 feet. This will provide you with the critical root radius in feet.

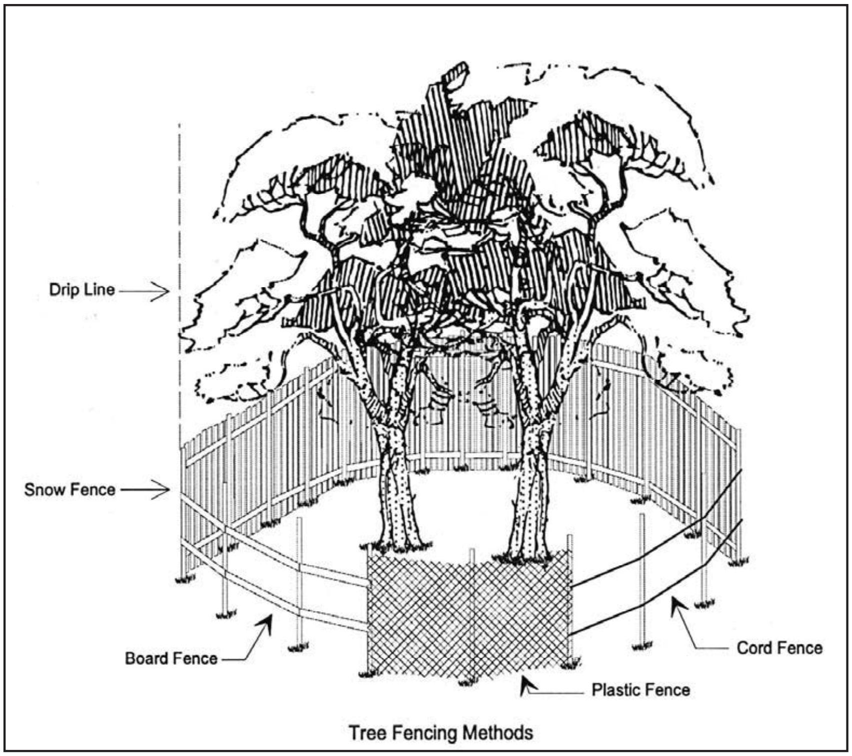


Figure 6.8 Erecting Barriers for Tree Protection Source: *Adapted from MU Guide 6885*

For example, a tree with a diameter (breast height) of 20 inches will have a critical root radius of 30 feet (60 foot diameter).

Construction

- Install temporary fences at tree driplines (at the critical root radius for sensitive tree species). To avoid compaction of the soil around desired trees, keep traffic, equipment and supplies off of the root systems. Figure 6.8 shows the correct method of erecting barriers for tree protection.
- Route the underground utilities according to plan. If possible, combine in one trench and route away from trees and potential planting sites.
- Use a brush cutter, rotary axe, or cut by hand instead of grading off brush to maintain the area within the tree canopy perimeter.

  Note: If grading beneath a tree's canopy is indicated on the plan:

  - Prior to construction activities, prune low hanging branches that may be damaged by equipment. To avoid tearing the bark from the tree while pruning, remove large branches with a stub-cut method. Figure 6.9 illustrates correct methods of pruning.
  - Minimize grading beneath the tree canopy. Avoid placing fill, or removing leaf litter or soil in the ungraded areas. Cut large roots instead of tearing them with equipment.

Stub-cut Method
First, make an undercut about one foot from the trunk. Then, cut through the branch near the first cut. Leave the tree's branch collar intact during the final cut to promote healing. Source: *Adapted from MU Guide 6866*

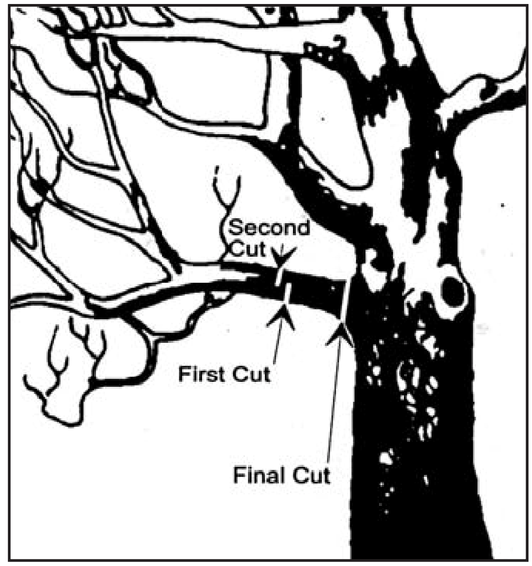


Figure 6.9 Proper Method of Pruning
Source: *Adapted from MU Guide 6866*

Construction Verification
Check the construction site to verify protective measures are being observed.

Troubleshooting
Consult with registered design professional such as an arborist or silviculturist if any of the following occur:

- A protected tree is accidentally injured by construction activities.
- If grade around a protected tree must be raised.

Maintenance, Inspection and Removal
- Remove fence around protected trees only after all construction is complete and all disturbed soil is stabilized.
- In spite of these precautionary steps some damage may occur to desired trees. If minor damage occurs, repair it immediately. Repair damage to limbs or roots by cutting off the damaged areas. Repair damage to bark by trimming the perimeter of the damaged area. If there is any question about the correct course of action, enlist the service of a professional arborist or silviculturist.
- Inspect trees for signs of stress, such as insect, disease and drought damage. Stressed trees should be watered during dry periods. Soak area under the canopy to a depth of 12- to 18-inches. Avoid fertilizing severely stressed trees until they become reestablished a year or two later. Treat insect and disease problems with a pesticide, if necessary, but be sure to follow instructions on the label. Or, employ a certified pesticide applicator to treat the problem.
- Remove temporary devices and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Trees show signs of damage such as wilting, early leaf drop in the fall or slow growth often caused by compaction.	Aerate the soil by pulling 12- to 18- inch deep cores in the soil within the dripline to assist movement of moisture and oxygen into the soil, then backfill with compost.
Trees killed during construction.	Remove after site completion and replace with new trees.

Parking and Material Laydown Areas

Figure 6.10 Laydown and storage areas should be neat and fully stabilized. Source: *ABC's of BMP's*

Practice Description

Many construction sites have a designated area for a construction trailer, parking and storage of construction material usually referred to as a laydown area. The area itself is not considered a best management practice but management of the area is.

Recommended Minimum Requirements

This area should be within the permitted area to be disturbed and should be located no closer than 100 feet from streams, wetlands, natural drainageways or other environmentally sensitive areas. Although the tendency is to park vehicles in shaded areas, this area should not be placed within the canopy of plants expected to remain on-site. The root zone of plants is generally as broad as the canopy. The area should be stabilized with vegetation or a small rock and gravel base depending on the amount of traffic in the area and should not contribute pollutants to the stormwater discharge. The area should be clearly marked on the SWPPP site map.

Construction

The parking and laydown areas as well as the traffic paths into and out of these areas should be stabilized. They are most often placed near the exit of the construction site and therefore can contribute to off-site sediment tracking if not managed properly.

Troubleshooting

Keep the area free and clear of trash and debris. Provide a location for trash disposal (e.g., dumpster) in an appropriate location. See the Solid Waste section under Pollution Prevention.

Maintenance, Inspection and Removal

- Inspect the area on a weekly basis and after rain events.
- Ensure that materials are properly stored and contained with Material Safety Data Sheets, or MSDS, information readily available.
- Removal of this temporary device must be performed and the site stabilized prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One-Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Sediment is being transported onto a public street when exiting the parking or laydown area; the area is eroding or traffic carries mud to the street.	Add rock over the area to stabilize it.
Vehicles sink into the soil caused by a soft subgrade.	Lay a geotextile membrane over the area and add a layer of small rock or gravel.

Temporary Stream Crossing

Practice Description

A temporary stream crossing is a short term crossing constructed over a stream for use by construction traffic. Temporary stream crossings can be designed as low water crossings, as an embankment with a culvert, or as a bridge with or without embankment approaches. Properly constructed, they prevent on going turbidity and streambed disturbance caused by construction traffic. Improperly designed and constructed stream crossings can cause upstream flooding, channel erosion during increased flows and failure of temporary crossings.

Temporary stream crossings may be subject to applicable federal, state and local regulations for in-stream modifications. Contact the U.S. Corps of Engineers and local authorities for possible permit regulations.

Recommended Minimum Requirements

Prior to start of construction, temporary stream crossings should be designed by a registered design professional. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process.

Drainage Area

Any size, however most temporary stream crossings occur on smaller headwater stream located within smaller drainages.

Slopes

Low Water Crossing

- 3:1 or flatter for downstream slope.
- 2:1 or flatter for upstream slope.

Culvert Crossing

- 2:1 or flatter for downstream and upstream slope.

Low Water Crossings

Water Flow

Shallow (less than 3 inches deep) or intermittent.

Traffic Usage

Light

Bank Height

Less than 5 feet.

Approaches

Slope of 5:1 or flatter.

Culverts

Minimum Diameter

- 18 inches or according to design plan.
- Large enough to pass the peak flow from the 2-year 24-hour rainfall event of the design storm.

Minimum Height of Fill Over Culvert

1 foot or 1/2 the pipe diameter, whichever is greater.

Culvert Length

Sufficient to extend the full length of the driving surface and the side slopes.

Construction

Locate the temporary stream crossing where erosion potential is low. Riffle locations within the channel generally are preferable locations to stream pools. Where practical, locate and construct stream crossings to serve as both temporary and permanent crossings to keep stream disturbance to a minimum.

Site Preparation

- Plan stream crossing in advance and attempt to construct them during dry periods to minimize stream disturbance.
- Follow all federal, state and local requirements on temporary road crossing.
- Ensure that all necessary materials are on the site before any work begins.
- Construct a bypass channel before undertaking other work. Refer to plans.
- Scarify the creek bed before placing fill.

Dewatering Site

- Stabilize the bypass channel with riprap or other suitable material when stream velocity exceeds that allowed for existing soil material.
- Divert the stream to the bypass channel.

Low Water Crossing

- Locate low water crossings only where normal flow is shallow (less than 3 inches deep) or intermittent, and where traffic is light. See Figure 6.11.
- Excavate the foundation for the temporary crossing. Place crossing straight across stream.
- Excavate roadways through the abutment approaches (bank) to the crossing according to the design plan.
- Place large rock riprap across the channel. Construct a wearing course of gravel or crushed rock over the riprap. Use geotextile between crushed rock and the riprap.
- Remove gravel and excess rock riprap as soon as it is no longer needed. Restore original contours to the channel, leaving rock riprap level with the streambed.

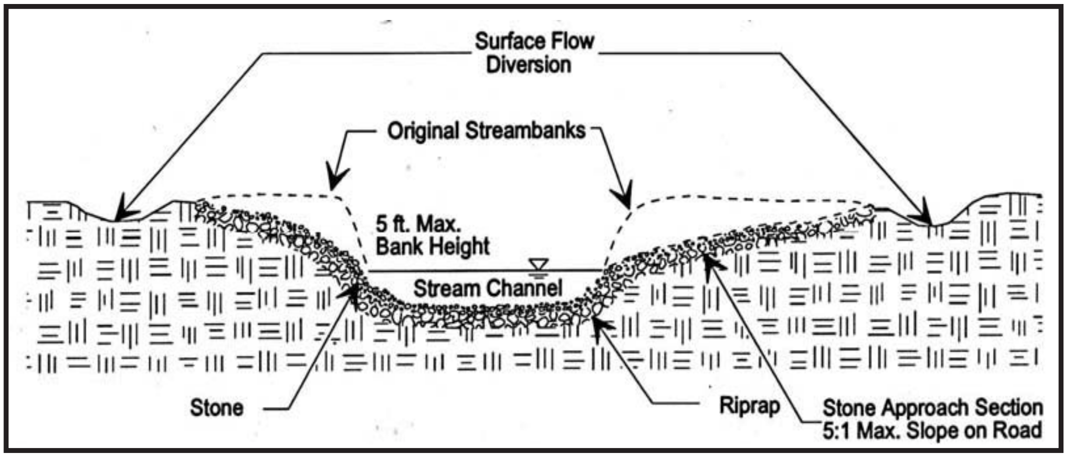


Figure 6.11 Typical low water stream crossing.

Culvert Crossing

- Excavate the foundation for the temporary stream crossing.
- Divert the stream flow. Prepare the pipe bedding. Situate the culvert pipe on a firm, even foundation and keep the culvert parallel to the direction of flow. See Figure 6.12.
- Place a 4-inch layer of moist, clayey, workable soil (not pervious material such as sand, gravel or silt) around the culvert. Compact by hand to at least the density of the embankment soil. (Don't raise the culvert from the foundation when compacting under the culvert haunches.)
- Extend the end of the culvert beyond the toe of the fill slope or install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.
- Remove culvert as soon as it is no longer needed. Restore streambed to original contour.

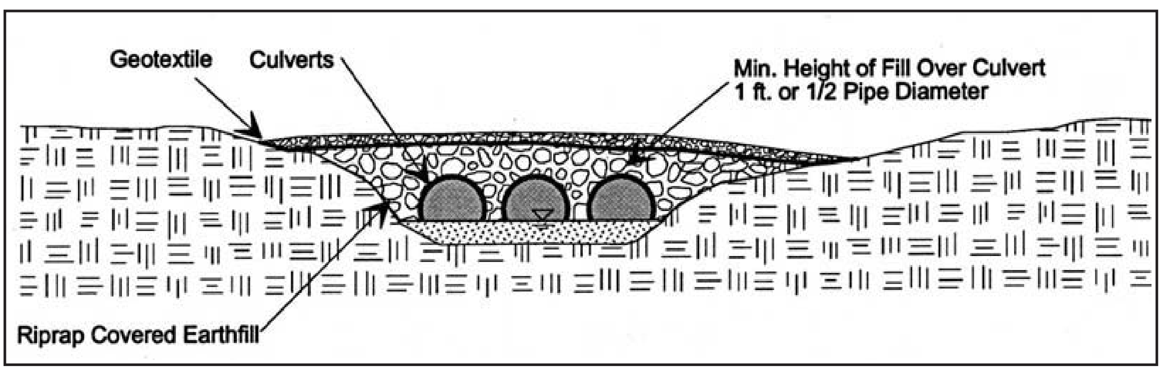


Figure 6.12 Typical temporary culvert stream crossing.

Bridges

- Properly designed bridges cause the least disturbance to the stream bed, banks and surrounding area. They are the preferred method for temporary stream crossings.
- Disadvantages to constructing temporary bridges include:
  - They are the most expensive option to construct
  - They are the greatest safety hazard if not adequately designed, constructed and maintained.
  - They cause a longer construction delay if washed out.
- Bridges must have stable abutments. It is recommended that a cable be tied to one corner of the bridge frame with the other end fastened to a secure object to prevent flood flows from carrying the bridge downstream where it may cause damage to other property.

Embankment for Bridges and Culverts

- Use fill from predetermined borrow areas. It should be clean, stable mineral soil free of roots, woody vegetation, rocks and other debris and must be wet enough to form a ball without crumbling yet not so wet that water can be squeezed out.
- Compact the fill material in 6- to 8-inch continuous layers over the length of the embankment. (One way is by routing construction equipment over the embankment so that each layer is traversed by at least one wheel of the equipment.)
- Protect the culvert with 2 feet of hand-compacted fill before traversing over the pipe with equipment.
- Construct and compact the temporary road crossing embankment to 10 percent above the design height to allow for settling.

Erosion Control

- Unlike permanent stream crossings, temporary stream crossings may be allowed to overtop during peak storm periods. However, the structure and approaches should remain stable. Keep any stockpiled fill located flood plains to a minimum to prevent upstream flooding and reduce erosion potential.
- Minimize the size of all disturbed areas and vegetate as soon as each phase of construction is complete. Riprap or establish vegetation on the slopes of the embankment in the temporary stream crossing.
- Direct all overland flow to the ditches along the approach roads at low velocity.

Safety

Because temporary stream crossings are potentially hazardous, take the following precautions:

- If site conditions warrant, construct guardrails or axle berms along the sides of the temporary stream crossing.
- Avoid steep slopes on the embankment; slopes should be kept as flat as possible (3:1 or flatter).
- Approach road slopes should be 5:1 or flatter.

Construction Verification

Check finished grade and both the size and orientation of culvert within the stream. Check to see if culverts are free of obstructions.

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography and stream conditions on-site indicate crossing will not function as intended; changes in plan may be needed.
- Design specifications for fill or conduit cannot be met; substitution may be required. Unapproved substitutions could result in the crossing being washed out.

Maintenance, Inspection and Removal

- Inspect the temporary stream crossing on a weekly basis and after each storm event. Pay close attention to the condition of the entrance and exit sections of the culvert pipe, the culvert joints, the abutment supports for bridges, all bridge connections and the amount of erosion on low water crossings.
- Add riprap to the culvert entrance and exit as necessary to protect the crossing.
- Periodically check the embankment for erosion damage, settling or slumping and repair immediately.
- Correct any problems immediately upon observing them. Do not wait until a scheduled weekly inspection to address a failure or potential hazard noted during routine activities.
- Remove debris, trash and other materials that restrict flow from the culvert or bridge.

Common Problems and Solutions

Problem	Solution
Piping failure along culvert caused by improper compaction, leaking pipe joints or use of unsuitable soil.	Repair piping damage and ensure culvert joints are sealed before properly compacting suitable soil around the culvert to prevent reoccurrence of the problem.
Erosion of embankment slopes caused by inadequate vegetation or improper grading and sloping.	Repair erosion damage and reevaluate erosion protection measures.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Return embankment to original configuration using properly compacted soil as specified in the original plans.
Slumping failure; caused by steep slopes.	Remove slide debris and replace with properly compacted soil.
Erosion and streambank caving below culvert; caused by inadequate outlet velocity protection.	Repair erosion damage and provide adequate outlet velocity protection.
Difficult and costly maintenance; caused by culvert not set in direction of flow in stream.	Consult registered design professional for other options.
Overtopping of roadway, ponding upstream of the culvert and erosion beneath the culvert caused by culvert entrance elevation set too high.	Repair erosion damage, and either reevaluate size and elevation of the culvert or raise the roadway elevation.
Frequent overtopping of roadway and increased erosion potential caused by the culvert or bridge opening being too small.	Repair erosion damage, and either resize the culvert or raise the roadway elevation.
Downstream scour and undermining of structure during flooding caused by roadway elevation too high.	Repair damage and resize or lower culvert.

Slope Breaks and Surface Roughening

Figure 6.13 Lot benching can shorten slope length and prevent erosion while improving the homeowner's yard. Source: *C. Rahm, NRCS, St. Charles County*

Practice Description

Slope breaks and surface roughening are practices that reshape the ground surface during construction to slow the surface overland stormwater flow and reduce slope length to reduce surface runoff velocities, therefore minimizing soil erosion and sedimentation during construction. Slope breaks and surface roughening are inexpensive ways to provide erosion control during construction prior to establishment of permanent vegetative cover.

Slope breaks, such as diversions or benches, can be used to reduce the length of continuous slopes and reduce erosion (See Diversions).

Recommended Minimum Requirements

Prior to start of construction, the site grading plan should be designed by a qualified professional. The grading plan should show disturbed areas, cuts, fills and finished elevations for all graded areas. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. During construction and reshaping of the topography a slope can be roughened once it has been graded out and prior to reaching final grade and vegetation establishment.

Schedule construction activities so the least amount of area is disturbed at one time.

Slope Breaks

Refer to plan. Table 6.1 provides suggested guidelines for spacing of slope breaks.

Table 6.1 Guidelines for Spacing Slope Breaks

Slope	Spacing (ft.)
33-50%	20
25-33%	40
15-25%	60
10-15%	80
6-10%	120
3-6%	200
< 3%	300

Source: Adapted from North Carolina Field Manual, 1991

Soil Surface Roughening

There are many types of surface roughening techniques such as track walking with a dozer up and down a slope or using a sheep's foot to create dimples in the soil surface. This increases infiltration and slows overland flow.

Surface Runoff

Avoid disturbing natural drainage ways, if possible. At each slope break, intercept runoff and channel it to storm drains or stabilized watercourses. If runoff contains sediment, protect drain inlets with a filter or divert water to a sediment trap or basin according to the site grading plan (See Inlet Protection, Temporary Sediment Trap and Sediment Basin).

Erosion Control

Graded areas should be stabilized with mulch, vegetation, crushed stone, riprap or other measures as soon as work is completed, or if work is interrupted for 14 or more working days. Soil surface roughening is both an erosion and sediment control technique and should not be combined with devices such as erosion control blankets. Blankets should be applied to smooth, fine-graded soil surfaces and will fail if used to cover roughened soil surfaces.

Slopes to be Vegetated

2:1 or flatter; 3:1 or flatter where maintained by tractor or other equipment. Slopes should be roughened during grading operations to retain water, increase infiltration and promote vegetative growth. Slopes should be protected from surface runoff while vegetation is being established (See Diversions, Perimeter Protection).

Borrow and Disposal Areas

As shown on the grading plan; these should be no closer than 100 feet to a streambank or sensitive area (e.g., wetland, spring, cave, sinkhole) in the absence of a specification and should not be placed in an area of stormwater conveyance. Stockpiles should be stabilized if not being used for 14 or more days according to the state and local regulatory requirements. If borrow or disposal locations are off-site, they should also be permitted and have a copy of the permit authorization on-site at all times. This is necessary if the off-site borrow or disposal area is used for this construction project only and disturbs one acre or greater requiring permit coverage.

Outlets for Breaks and Diversions

Stabilized outlets should be provided for runoff from the disturbed area in order to retain sediment on-site.

Construction

Site Preparation

- Erosion and sedimentation control measures should be installed as specified and in the sequence shown on the design plan.
- Prior to excavation activities of any type, call1-800-DIG-RITE (344-7483) to obtain utility locations.
- Remove and stockpile topsoil (see Topsoiling) if subsoils will not support plant growth.
- Clear and grub areas to be filled and remove trees, vegetation, roots and other debris.
- Check fill to make sure it is does not contain brush, rubbish, oversized rocks or other objectionable material.
- Place fill in layers and compact as specified by the grading plan. Do not use frozen, excessively soft or high organic content material.
- Do not place fill on frozen subgrade, as it may cause an unstable condition due to potential differential settlement when the soil thaws.

Grading

- Construct slope breaks as shown on the grading plan, or in accordance with the recommendations of Table 6.1. A typical slope break is illustrated in Figure 6.14.
- Keep diversions and other water conveyance measures free of sediment during all phases of development.
- Avoid grading and building in areas of seepage. If this cannot be avoided, then install subsurface drains (See Subsurface Drains) in areas where seepage interferes with the grading operations, or where required to improve slope stability or soil bearing capacity.
- Permanently stabilize graded areas immediately after final grading is complete. Use temporary stabilization measures on graded areas when work is to be interrupted or delayed for 14 working days or longer.

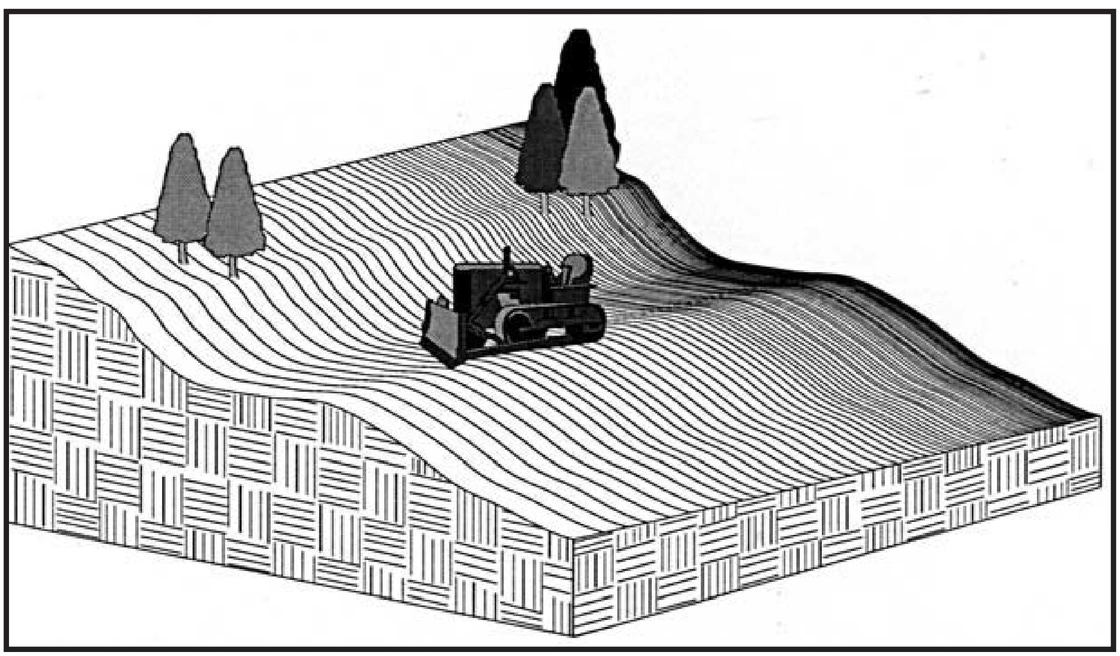


Figure 6.14 Typical Slope Break

Construction Verification

Check all finished grades for conformance with grading plan and correct as necessary.

Maintenance, Inspection and Removal

- Periodically inspect all graded areas and the related erosion and sedimentation control practices, as required by the construction general permit, especially after heavy rainfalls. Clean sediment out of diversions and other structures as needed. If washouts or breaks occur, repair them immediately.

Figure 6.15 Track walking with a dozer up and down the slope provides horizontal grooves to reduce stormwater flow volumes and velocity therefore reduces potential for erosion of the slope. Source: *ABC's of BMP's, LLC*

- Remove this is a temporary device and stabilize the site *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate grading plan will be ineffective or unfeasible.	Consult with design professional
Seepage is encountered during construction.	It may be necessary to install drains. Dewatering shall be performed in accordance with regulatory requirements.
Design specifications for seed variety, seeding dates, erosion control materials or timeframes cannot be met.	Substitutions may be required. Unapproved substitutions could result in erosion and lead to failure of erosion control measures.
Prominent rill and gully erosion caused by slope breaks being too far apart.	Construct intermediate slope breaks.
Difficulties achieving proper compaction of fill caused by subgrade being soft, contains oversized rocks or has high organic content.	Undercut and replace unsuitable subgrade soil.
Slope is unstable or has reduced bearing capacity caused by a high water table	Install subsurface drains to lower water table.

Topsoiling: Removal, Stockpiling and Replacement

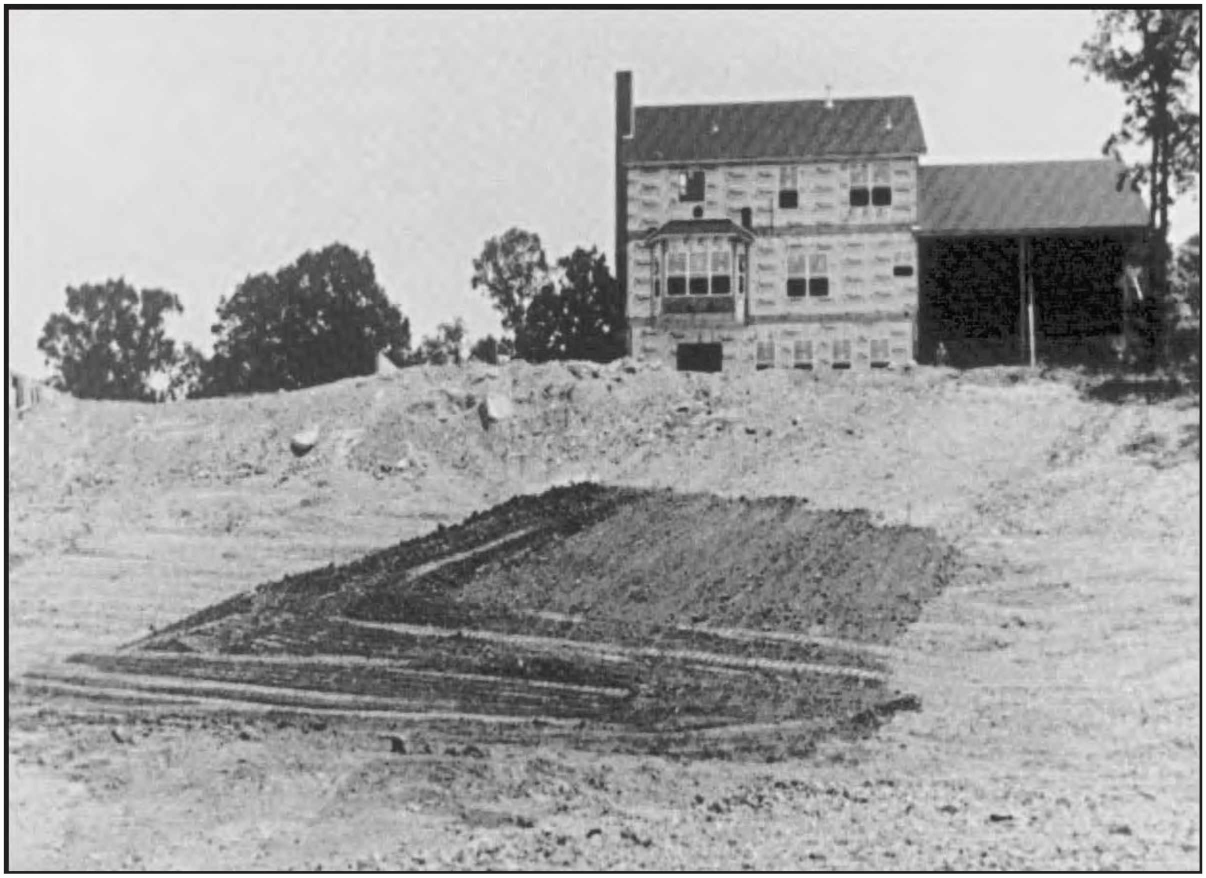


Figure 6.16 It's important to mix or incorporate topsoil with the underlying subsoil to prevent sloughing on sloping soils.
Source: *C. Rahm, NRCS. St. Louis Co.*

Practice Description

Topsoiling is a method of preserving the topsoil prior to construction, stockpiling it and using it after construction to help establish vegetation on a construction site. Stockpiling is also used for storage of other soils and construction material such as fill material. These practices apply to areas on a site to be disturbed by excavation, compaction or filling, and where vegetation is to be reestablished.

Recommended Minimum Requirements

Prior to the start of construction, topsoiling should be designed by a qualified professional. The existing soil should be tested to ensure the material to be saved is topsoil and helps with vegetation establishment and long-term, permanent growth. The location of other material to be stockpiled on the site should be shown on the site map and stabilized according to the regulations. Refer to the plans and specifications throughout the construction process.

Topsoil

- Surface soil or top layer of undisturbed soil, usually richest in organic matter and nutrients.
- Should be free of debris, trash, stumps, large rocks, roots and noxious weeds. It should contain no substance potentially toxic to plant growth.

Minimum Soil Depth

- 24 inches of total soil depth over bedrock (combined topsoil and subsoil); from 8- to 12-inches of total soil depth over loose sand or rock.
- The top 4- to 6-inches of soil must be good topsoil, rich with organic matter, microorganisms and not more than 50 percent clay content to ensure good vegetation establishment and growth on a permanent basis.

pH Range

- From 6.0 to 7.5.
- If the pH is less than 5.2, lime should be incorporated in accordance with soil test results.

Construction

Site Preparation

- Establish all perimeter erosion and sediment control practices, (e.g., sediment barriers, diversions, grade stabilization structures, berms, dikes, sediment basins) before stripping.

Stripping

- Strip topsoil from areas that will be disturbed by excavation, filling or compaction by equipment.
- Determine depth of stripping by taking soil cores at several locations within each area to be stripped.
- Make sure the soil being saved is topsoil. It should have a minimum of five percent organic material and a clay content of less than 50 percent.

Stockpiling

- Do not place topsoil or other stockpiles near areas of water (e.g., conveyances, ditches, swales).
- Do not place stockpiles on impervious surfaces or within 50 feet of storm drain inlets.
- Avoid placing topsoil or stockpiling other material on steep slopes. Side slopes of stockpile should not exceed 2:1.
- Use sediment fences or other barriers where necessary to retain sediment.
- Protect topsoil and other stockpiles with temporary seeding or other soil stabilization techniques as soon as possible, but not more than 14 working days after formation of the stockpile. If stockpiles will not be used within 12 months, they should be stabilized by permanent vegetation to control erosion and weed growth.

Grading

Established grades should be maintained according to the approved plan and should not be altered by adding topsoil.

Liming of Subsoil

Where the pH of the existing subsoil is below 5.2, incorporate agricultural limestone in amounts indicated by soil tests or specified for the seeding mixture to be used (See Temporary or Permanent Seeding). Incorporate lime into the subsoil to a depth of at least two inches by disking. Retest the soil to determine the pH and if pH is not 5.2 or higher, repeat the process.

Roughening

Immediately prior to spreading topsoil, loosen the subgrade by disking or scarifying to a depth of at least two inches to ensure bonding of the topsoil and subsoil.

Spreading Topsoil

- Spreading frozen or muddy topsoil can prevent proper grading or seeding. Uniformly spread topsoil to a minimum compacted depth of four inches. For long-term growth of vegetation without irrigation, minimum soil depth (subsoil and topsoil) should be 8- to 12-inches over loose sand or rock fragments, and 24 inches over bedrock.
- Prior to the establishment of final vegetation, the topsoil should be final graded so it is smooth with no clods greater than one inch in diameter.

Construction Verification

Verify that topsoil was spread evenly and incorporated with underlying subsoil.

Maintenance and Inspection

- Maintain erosion control devices over topsoil until vegetation is fully established with a density of 70 percent over the entire area.
- Inspect topsoiled areas frequently until vegetation is established.
- Repair eroded or damaged areas and revegetate.

Common Problems and Solutions

Problem	Solution
Poor or no vegetation establishment caused by topsoil pH too low.	Add agricultural limestone to adjust pH.
Poor or no vegetation establishment caused by topsoil containing sterilants or toxic chemicals.	Remove contaminated topsoil and replace.
Poor or no vegetation establishment caused by topsoil being too high in clay content or too low in organic material and microorganisms.	Add organic material.
Poor vegetation establishment caused by topsoil being compacted too much during application.	Loosen by disking or scarifying and reseed.
Poor drainage and possible sloughing on steep slopes caused by topsoil not properly bonded to subsoil.	Remove topsoil, roughen subgrade and respread topsoil.
Inadequate vegetation establishment caused by topsoil removed during construction and not replaced.	Add topsoil with a minimum of 5 percent organic material, a clay content under 50 percent, fertilize according to soil test results, reseed or sod site, and apply water to establish vegetation.

SECTION 2: POLLUTION PREVENTION AND GOOD HOUSEKEEPING

Pollution prevention includes best management practices that need to be set up at the beginning of the project. Pollution prevention practices consist of site management considerations that do not fit into other categories of erosion or sediment controls, such as materials management, good housekeeping, spill prevention, spill clean up and concrete washout.

Good housekeeping entails keeping the site clean and reducing water and air-borne pollutants. Best management practices include effective control of solid waste, sanitary waste, petroleum, hazardous waste and material storage.

This section addresses general components of pollution prevention at the construction site. Each site should be evaluated for more specific pollution prevention needs. Some protection measures are required by federal, state or local regulations. For example, any project disturbing an acre of more of land requires a land disturbance permit. The permit in turn requires a Stormwater Pollution Prevention Plan, or SWPPP (See Chapter 1).

The Stormwater Pollution Prevention Plan should contain sections for each of the following issues on a construction site. In addition, these practices should be routinely inspected with all other best management practices to ensure pollution sources are contained on the construction site and that pollutants do not mix with soil or stormwater.

Materials Management

Material delivery, handling and storage can generate significant pollution. The site superintendent needs to ensure best management practices are followed to minimize or eliminate the discharge of material pollutants to the storm drain system or watercourse.

Inventory

The site superintendent should develop and maintain an inventory of materials that will be stored outside on the site during construction. For example:

- ☐ Pipe, fittings and joint compounds for underground utility piping.
- ☐ Gravel and stone bedding material.
- ☐ Concrete forming materials.
- ☐ Other. (Specify) ______________________________

Delivery

Locations for delivery should be determined and clearly marked. Where beneficial, visibly place signs with delivery instructions for the drivers. Employees trained in emergency spill clean-up procedures need to be present when dangerous materials or liquid chemicals are unloaded.

Storage

Fuels, oils and other petroleum products (e.g., forming oils and compounds; fertilizers; pesticides) or any other hazardous or toxic compounds should be stored under cover and not allowed to come in contact with stormwater on the site. On-site storage should meet all local, state and federal secondary containment rules and regulations. Additionally, local ordinances may require fencing and security measures for storage of these products.

Do not store hazardous chemicals, drums, or bagged materials directly on the ground. Place these items on a pallet and under cover in secondary containment.

Do not store incompatible materials, such as chlorine and ammonia in the same temporary containment facility.

Solid Waste Management

Figure 6.17 This dumpster is in need of routine maintenance and the trash and debris around the area must be disposed of in a proper manner. Source: ABC's of BMP's, LLC

The general contractor is responsible for disposing of all solid waste from the site in accordance with state and local laws and regulations. Dumpsters or other collection containers should be provided as needed and should be covered at all times to reduce the spread of litter and avoid public nuisance and vector concerns. Solid waste may not be buried on the site and may not be open burned except in conformance with the Missouri Air Conservation Law and regulations. Open burning violations are also a violation of the Missouri Solid Waste Management Law.

All solid wastes removed from the construction site must go to a permitted transfer station or landfill and cannot be taken to another unpermitted location for consolidation or processing. Material may be sorted on-site and diverted to acceptable reuse or recycling.

Deconstruction Waste Recycling

Recycling deconstruction waste is one way to minimize solid waste disposal costs and pollution. For information about local outlets for deconstruction materials, contact your area Solid Waste Management District.

There are 20 Solid Waste Management Districts in the State of Missouri. Search their contact information at:

- Solid Waste Management District Contacts located at www.dnr.mo.gov/env/swmp/swmd/swmdinfo.htm or by calling 800-361-4827.
- Missouri Construction and Demolition Waste Guidance www.dnr.mo.gov/env/cdwaste.htm.
- Additional information is available at:
  - Mid America Regional Council (Kansas City region) at 816-474-4240 or www.recyclespot.org.
  - Construction Industry Compliance Assistance Center at www.cicacenter.org/
  - Toolbase Services: Construction Waste Management at www.toolbase.org/Best-Practices/Construction-Waste/construction-waste-management.

Recommended Minimum Requirements

- Solid waste management procedures and practices are designed to minimize or eliminate the discharge of pollutants to the drainage system or to watercourses as a result of the creation, stockpiling or removal of construction site wastes.
- Construction projects should be designed and implemented to minimize the amount of wasted materials.
- Materials should be purchased with minimal packaging.
- Solid waste management procedures and practices must be implemented on all construction projects that generate solid wastes. Solid wastes that are commonly found on construction and demolition sites include but are not limited to:
  - Construction wastes (e.g., lumber, wood sheeting products, steel and metal scraps, sawdust, pipe and electrical cuttings, non-hazardous equipment parts, polystyrene (Styrofoam), wall board, miscellaneous types of insulation, roofing materials, empty containers and other materials used to transport and package construction materials).
  - Landscaping vegetation waste and landscape plant containers.
  - Packaging materials.
  - Litter, including food containers, beverage cans, coffee cups, paper bags, plastic wrappers and smoking materials, including litter generated by the public.

Employee Training

Employees should be trained and educated as part of good housekeeping and pollution prevention on a construction site.

- Instruct employees and subcontractors about identification of solid waste and hazardous waste.
- Educate employees and subcontractors about solid waste storage and disposal procedures.
- Hold regular meetings to discuss and reinforce disposal procedures. incorporate procedures into regular safety meetings.

- Require employees and subcontractors follow solid waste handling and storage procedures.
- Prohibit littering by employees, subcontractors and visitors.
- Minimize production of solid waste materials wherever possible.

Collection, Storage, Recycling and Disposal

- Construction and landscaping material waste should be recycled and reused as much as possible.
  - Landscaping vegetation should be shredded and used as mulch when possible.
  - Materials from demolished structures should be recovered for reuse or recycling when possible.

    Note: Any separating of recoverable materials for reuse or recycling must occur on the property of origin. Solid waste cannot be removed to another location for sorting or separating without a permit from the Department of Natural Resources' Solid Waste Management Program.
  - Salvage or recycle useful vegetation debris, packaging or surplus building materials when practical. For example, trees and shrubs from land clearing can be converted into wood chips, and then used as mulch on graded areas. Recycle wood pallets, cardboard boxes and construction scraps.
- Provide dumpsters of sufficient size and number to contain the solid waste generated by the project. Dumpsters should be covered at all times and be properly serviced.
- Provide trash receptacles in the permittee's yard, field trailer areas and at locations where workers congregate for lunch and break periods.
- Locate solid waste storage areas at least 50 feet from drainage facilities and watercourses and should not be located in areas prone to flooding or ponding of water.
- Collect construction debris and litter from work areas within the construction limits of the project site on a daily basis and place in watertight dumpsters, regardless of whether the litter was generated by the permittee, the public or others.
- Empty dumpsters weekly from the site. Dispose of the contents in accordance with Missouri State solid waste regulations. While demolition and construction debris typically do not emit a lot of odors, food waste from workers can cause an odor problem and attract public complaints.
- Properly dispose of the waste at a permitted solid waste transfer station or a permitted sanitary or demolition landfill.
- Do not place collected litter and debris in or next to drain inlets, stormwater drainage systems or watercourses.
- Prohibit littering on the project site and perform periodic litter removal from the area to reduce public nuisance concerns from airborne and waterborne litter.
- To prevent clogging of the storm drainage system, litter and debris removal from drainage grates, trash racks, and ditch lines should be a priority.
- Remove construction debris and waste from the site as necessary to maintain a safe environment and to avoid public nuisance issues related to airborne and waterborne trash or vectors.

- Store or stack construction material visible to the public in an orderly manner and manage it to protect the value of the material. Materials stored in a waste like manner are regulated by the Missouri Department of Natural Resources’ Solid Waste Management Program or Kansas Department of Health and Environment’s Bureau of Waste Management.
- Prevent stormwater run-on from contacting stored solid waste through the use of covered containers. Recovered or recycled materials should be covered, or the area in use should include berms, dikes, other temporary diversion structures or the use of measures to elevate waste from site surfaces to avoid contact with stormwater.
- Construction and highway planting waste not stored in watertight dumpsters need to be securely covered from wind and rain by covering the waste with tarps or plastic sheeting or protected in conformance with the applicable disturbed soil area protection section.
- Dumpster washout on the project site is typically not allowed by the permits.
- Notify trash hauling contractors that only watertight dumpsters are acceptable for use on-site.
- Store potentially hazardous waste from non-hazardous construction site waste.
- Keep the site clean of litter debris.
- Make sure that toxic liquid wastes (e.g., used oils, solvents, and paints) and chemicals (e.g., acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for construction debris.
- Dispose of non-hazardous waste in accordance Missouri State solid waste regulations.
- Remove this temporary device and stabilze the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Maintenance, Inspection and Removal

- Inspect all dumpsters on a weekly basis and after rain events.
- Remove full dumpsters from the project site and dispose the contents in accordance with Missouri Solid Waste Management Law and regulations.
- Handle and dispose litter stored in collection areas and containers properly.
- Remove construction debris and waste from the site as necessary. The debris and waste cannot cause a public nuisance or health hazard.

Common Problems and Solutions

Problem	Solution
Trash and debris blowing out of dumpster caused by lack of a cover or overfilling.	Cover dumpster and debris with a tarp or other waterproof cover until the dumpster service provider can bring a new dumpster or empty the existing one. Insist on a unit with a properly working lid or cover, if not provided.

Sanitary Waste Management

Figure 6.18 Typical port-a-potty with secondary containment and tie downs. Source: BFA Inc.

Sanitary waste management consists of procedures and practices to minimize or eliminate the discharge of sanitary or septic waste materials to the storm drain system or watercourses. The general contractor is responsible for providing sanitary facilities appropriate to the number of employees on the site. Sanitary and septic waste management practices are to be implemented on all construction sites that use temporary or portable sanitary or septic waste systems. Sanitary waste may only be disposed of in accordance with the Missouri Clean Water Law.

Recommended Minimum Requirements

Written Procedures and Practices

Written procedures and practices should be referenced in the stormwater pollution prevention plan, or SWPPP. Plans should be posted on the portable facilities and at the office. The site superintendent and field personnel should ensure procedures and practices are followed at all times.

Documentation

Log all education, maintenance, inspection and removal activities in case questions arise during inspections and for reference when troubleshooting problems.

Education

- Educate employees, subcontractors and suppliers about potential dangers to humans and the environment from sanitary or septic wastes.
- Instruct employees, subcontractors and suppliers in identification of sanitary and septic waste.
- Educate employees, subcontractors and suppliers about sanitary and septic waste storage and disposal procedures.
- Hold regular meetings to discuss and reinforce disposal procedures. Incorporate procedures into regular safety meetings.
- Establish a continuing education program to update new employees.

Location, Storage and Disposal Procedures

- In order to reduce the risk of tipping and spillage, temporary sanitary facilities should be firmly anchored to the ground and located where they are protected from high winds.
- Temporary sanitary facilities should be located a minimum of 50 feet away from drainage facilities, watercourses and traffic circulation. Avoid locating sanitary facilities on an impervious surface. Secondary containment may be required for sanitary facilities located on impervious surfaces.
- Wastewater must not be discharged onto or buried within the construction site.
- If sanitary and septic systems discharge directly into sanitary sewer systems, where permissible, the contractor needs to comply with applicable city, county or sewer district requirements. Use of portable toilet facilities on the construction site may require a permit from the local municipality or health department.
- If using an on-site disposal system, such as a septic system, the contractor may need to comply with county health department requirements.
- Properly connect temporary facilities that discharge to the sanitary sewer system to avoid illicit discharges.
- Ensure sanitary and septic facilities are maintained in good working order. It is recommended that a licensed contractor be used or consulted.
- It is recommended to use reputable, licensed sanitary and septic waste haulers.

Maintenance, Inspections and Removal

- Inspect all sanitary waste management devices weekly and after each rainfall event that results in stormwater runoff – and as strong wind conditions occur. Discuss maintenance issues and requirements with the sanitary facility provider before installation.
- Make sure routine and timely disposal of waste materials is occurring.
- Respond immediately to correct problems caused by damage to or tipping of portable units. Clean up and dispose of spills in accordance with state and local regulations. Determine response times for waste haulers and adjust the callout routine to ensure timely disposal of waste is occurring.

- Anticipate fluctuations in facility usage based on the number and location of concurrent construction activities as well as variations in the total number of workers present on the site. Relocate facilities, add units, or increase the frequency of maintenance calls to waste haulers as necessary to make sure the units are convenient for use and do not overfill.
- Remove this temporary device and stabilze the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Waste management device falls over or is blown over by wind, caused by improper anchoring.	Anchor or otherwise tie down the device securely.
The sanitary or septic system facility is overflowing, caused by failure to routinely empty and dispose of the waste.	Call the sanitary facility provider to empty the waste immediately and dispose of it properly. Ensure the person in charge of the facility is clearly aware of their responsibility to oversee proper inspection and maintenance. Implement additional education for all involved.

Petroleum and Hazardous Waste Management

Figure 6.19 This site has a designated vehicle maintenance area with all petroleum products located within secondary containment areas. Source: BFA, Inc.

Petroleum and hazardous wastes must be managed and controlled on a construction site to ensure they do not contaminate the stormwater flow and discharge from the site. The site superintendent and field personnel must ensure proper management of petroleum and hazardous waste by providing secondary containment of petroleum and hazardous substances, and by ensuring proper use, containment and disposal. Site superintendents and field personnel should strive to reduce, reuse and recycle materials as much as possible and avoid purchasing, storing and using more petroleum and hazardous waste material than necessary.

While this is a guidance document, some of the information in this section might actually be required under federal, state or local regulations. The general contractor and site superintendent need to ensure they have a clear understanding of federal, state and local requirements, and they should ensure all field personnel are properly educated and trained in these areas.

Recommended Minimum Requirements

Ensure hazardous waste management practices are implemented on construction projects that generate any waste from the use of:

- Petroleum products.
- Asphalt products.
- Concrete curing compounds.
- Pesticides.
- Acids.
- Paints.
- Stains.
- Solvents.
- Wood preservatives.
- Roofing tar.
- Soil binders
- Any materials deemed a hazardous waste according to federal and state laws and regulations.

More information about federal and Missouri laws and regulations is available on the Missouri Department of Natural Resources' Hazardous Waste Program Web page at www.dnr.mo.gov/env/hwp/lawsregs.htm or by calling 800-361-4827 or 573-751-3176

More information about Kansas laws and regulations is available on the Kansas Department of Health and Environment Web page www.kdheks.gov/waste/ or by calling 785-296-1600.

Documentation

Log all education, maintenance, inspection and removal activities in case questions arise during inspections and for reference when troubleshooting problems.

Education And Training

- Educate employees and subcontractors about potential dangers to humans and the environment from hazardous wastes.
- Train employees and subcontractors about hazardous waste delivery, handling, storage and disposal procedures.
- Instruct employees and subcontractors about:
  - Identification of hazardous and solid waste.
  - Safety procedures for common construction site hazardous wastes.
- Hold regular meetings to discuss and reinforce hazardous waste management procedures along with safety procedures.

Petroleum Products

All vehicles kept on-site need to be monitored for leaks and receive regular preventive maintenance to reduce the chance of leakage. Leaking vehicles and construction equipment should be removed from service until the problem has been corrected. Petroleum products should be stored in tightly sealed containers are clearly labeled. Any asphalt substances used on-site should be applied according to the manufacturer's specifications and recommendations. Empty containers should be disposed of per manufacturer's recommendations and meet all federal, state and local regulations.

Fueling and Servicing

No fueling, servicing, maintenance or repair of equipment or machinery should be done within 100 feet of a stream, or within 150 feet of a classified stream, losing stream or sinkhole. Tarps or drop cloths and drip pads should be used when servicing, repairing or performing maintenance on construction equipment in the field. When work is complete, the contaminated materials should be disposed of appropriately.

Disposal of Petroleum and Hazardous Materials

No fuels, oils, lubricants, solvents, coolant, washer fluid or other hazardous materials can be disposed of on-site. All hazardous material must be properly disposed of in accordance with State law.

- For guidance, contact 800-361-4827 in Missouri or 785-296-1667 in Kansas.

Setup, Storage, Maintenance, Inspection and Removal

- Do not store hazardous chemicals, drums, or bagged materials directly on the ground. Place these items on a pallet and under cover in secondary containment.
- Incompatible materials, such as chlorine and ammonia, must not be stored in the same temporary containment facility.
- The site superintendent should keep an accurate, up-to-date inventory of material delivered and stored on-site.
- Minimize material inventory when stored on-site (e.g., only a few days supply).
- Employees trained in emergency spill clean-up procedures need to be present when dangerous materials or liquid chemicals are unloaded.
- Locate temporary storage areas away from vehicular traffic and in upland areas.
- Spill containment is highly recommended for chemical storage and transfer areas. (See Spill Prevention and Control).
- Locate an ample supply of appropriate spill clean-up materials near storage areas.
- Keep storage areas clean, well organized and equipped with ample clean-up supplies as appropriate for the materials being stored.
- Post proper storage instructions at all times in an open and conspicuous location. Storage areas should be clearly marked, directing placement of containers and materials.
- Store materials in their original containers. Maintain original product labels on the container where they can be easily seen. Damaged or otherwise illegible labels should be replaced immediately.
- Store bagged and boxed materials on pallets. Do not allow materials to accumulate on the ground. Cover bagged and boxed materials during non-working days and prior to rain events.
- Store materials exposed to precipitation in watertight, structurally sound, closed containers. All chemicals should be stored in approved containers and not exposed to stormwater.

Secondary Containment

Materials such as fuel (e.g., gasoline, diesel, kerosene), oil products (e.g., motor oil, transmission fluid, hydraulic oils, grease), miscellaneous liquids (e.g., windshield washer fluid, antifreeze, paint, concrete cure, liquid fertilizer, concrete sealer, calcium chloride, salt brine) should be stored in secondary containment. This represents a partial list.

- Throughout the rainy season, each secondary containment facility should have a permanent cover. The facility should at least be covered during non-working days, prior to rain events and during rain events. The cover should include side wind protection. The cover should be securely fastened to be effective during all rain events, overnight and during any extended period of time when the site will be left unattended.

- No not allow rainwater to collect within the secondary container. Remove any rainwater waste that does collect within the structure immediately so it does not reduce the capacity to contain spills or leaks. Collect and properly dispose contaminated rainwater, spills and leaks in accordance with local, state and federal regulations. (See Spill Prevention and Control).
- Provide Adequate cover to the secondary container to prevent the entry of rainwater. Depending on the type of secondary container used, adequate cover could include a tarpaulin, fitted lid or roof.
- Provide a temporary containment facility for a volume able to contain precipitation from a 24-hour, 25-year storm event, plus the greater of 10 percent of the aggregate volume of all containers or 100 percent of the capacity of the largest container within its boundary, whichever is greater.
- A temporary containment facility should be impervious to the materials stored therein for a minimum contact time of 72 hours.

Provide sufficient separation between stored containers, secondary or otherwise, to allow for spill cleanup and emergency response access. (See Spill Prevention and Control).

Inspection

- Inspect all construction equipment prior to use each day for leaks or spills.
- Inspect all areas where petroleum and hazardous waste materials are stored.
    - Inspect weekly and after each rainfall event that results in stormwater runoff.
    - Repair or replace perimeter controls, containment structures, covers and liners as needed to maintain proper function.
- Collect and clean up spills, leaks or accumulated rainwater and dispose of appropriately.
- If a rain event causes secondary containment devices to fill with water, dewater the containment system in the appropriate manner.
- Make sure routine and timely disposal of waste materials occurs.

Removal

- Collect, remove and dispose hazardous waste only at authorized disposal areas.
- Remove and stabilize petroleum and hazardous materials stored on the construction site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (See Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Temporary containment device is full or overflowing after a rain event due to failure to dewater or lack of adequate storage volume.	Contain the discharge and ensure it does not leave the site. Ensure dewatering occurs in a timely manner following storm events. If necessary, enlarge the containment system to allow additional storage volume, and maintain the system appropriately.
Sheen shows up in dewater discharge, due to failure to remove sheen prior to dewatering.	Ensure there is no visible sheen on rainwater prior to dewatering. Use appropriate absorbents to recover materials to the extent possible. Properly dispose of absorbent materials and then finish dewatering.

Spill Prevention and Control

Spill prevention and control procedures and practices are necessary to prevent and control spills in a manner that minimizes or prevents the discharge of spilled material to the drainage system or watercourses. This includes calling the spill hot line to report the spill.

It is not the intent of this guidance to supersede or replace normal site assessment and remediation procedures concerning hazardous materials. (See Petroleum and Hazardous Waste Management). Significant spills, releases or contamination warrant an immediate response by trained professionals.

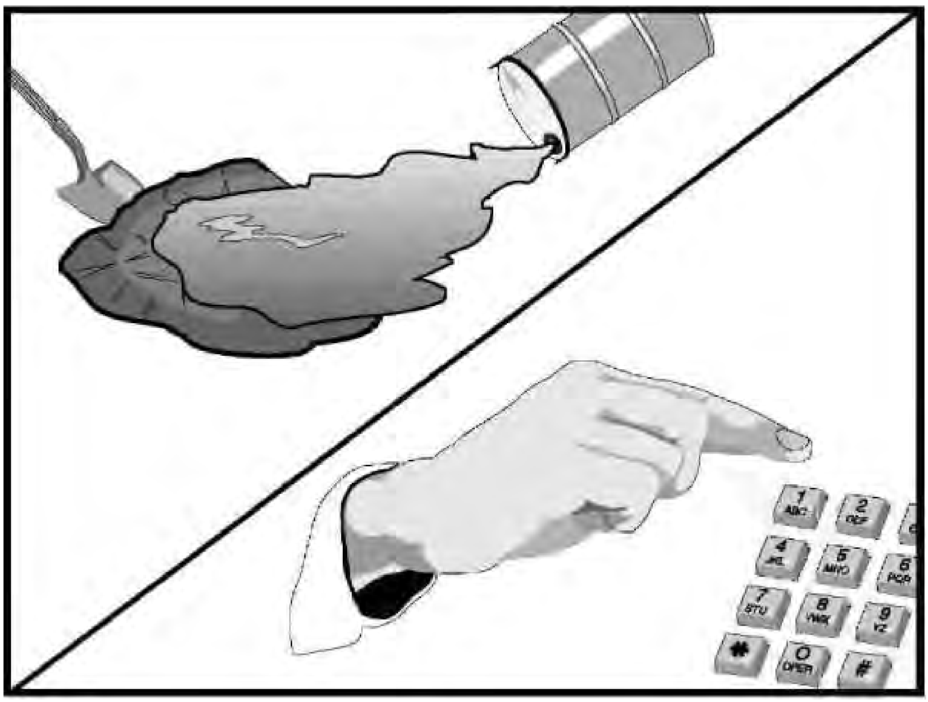


Figure 6.20 Contain spills and report them to the appropriate agency .

In Missouri, contact the department's emergency spill hot line at 573-634-2436.
In Kansas, contact the KDHE 24-hour spill hotline at 785-296-1679.

Recommended Minimum Requirements

Documentation

Log all education, maintenance, inspection, clean up and removal activities in case questions arise during inspections and for reference when troubleshooting problems.

Education and Training

- Ensure the contractor provides adequate training to the site superintendent and all field personnel about the proper protocol for reporting and cleaning up spills.
- Educate employees and subcontractors about potential dangers to humans and the environment from spills and leaks.
- Educate employees and subcontractors about what a “significant spill” is for each material they use and what is the appropriate response for “significant” and “insignificant” spills.
- Hold regular meetings to discuss and reinforce appropriate disposal procedures.Incorporate disposal procedures into regular safety meetings.
- Establish a continuing education program to train new employees.

In addition to good housekeeping and material management practices listed previously, the following practices need to be followed for spill prevention and clean-up:

- The spill response plan should be documented and its availability should be referenced in the written stormwater pollution prevention plan or SWPPP.
- Clearly post methods on-site for storage and spill cleanup, including manufacturer’s recommendations.
- Make site superintendent and field personnel aware of the procedures and the location of material safety data sheets, or MSDSs, information and cleanup supplies. For federal requirements for Spill Controls and Countermeasure Plans, or SPCC, see 40 CFR Part 112 on the Web at www.campuserc.org/virtualtour/grounds/WasteOils/Pages/SPCCDetails.aspx.
- Keep material and equipment necessary for spill cleanup in the material storage area on-site. Equipment and materials include, but are not be limited to, brooms, dust pans, mops, rags, gloves, goggles, kitty litter, sand, sawdust and plastic and metal trash containers specifically for this purpose.
- Clean up all spills immediately after discovery and properly containerize spills for proper disposal. Burial is not acceptable.
- Keep the spill area well ventilated. Personnel need to wear appropriate protective clothing to prevent injury from contact with a hazardous substance.

Reporting

Spills of toxic or hazardous material must be reported immediately to the appropriate state or local government agency, pursuant to reportable quantity regulations for specific materials or if a waterway is, or may be, impacted. Each county should have a Local Emergency Planning Committee, or LEPC. If you are unable to contact the committee directly, contact your local fire department, city hall or county courthouse. When permits are applicable, the permittee or authorized representative is required to notify the Missouri Department of Natural Resources or Kansas Department of Health and Enviroment’s Environmental Emergency Response in accordance with 40CFR117 and CFR302 as soon as they have knowledge of the discharge of any hazardous substance or petroleum product in excess of the reportable quantity.

- In Missouri, contact the 24-hour emergency spill hotline at 573-634-2436.
- In Kansas, contact the 24-hour emergency spill hotline at 785-296-1679.

In Missouri, state law requires the responsible party (spiller) to report petroleum product releases greater than 50 gallons to the Missouri Department of Natural Resources at 573-634-2436 at the earliest practical moment after discovery. If the release is from an underground storage tank, or UST, or piping, the reportable quantity is 25 gallons or more. Reports are also required for above ground storage tanks, or AST, that have released 50 gallons or greater. Further, federal law requires the responsible party to report any release of oil if the oil reaches or threatens any waterway. The definition of waterway includes sewers, groundwater, wetlands, lakes, creeks, streams, rivers and areas that may not have running water in them at the time, such as road ditches that drain into other waterways.

Adjust spill prevention plan to include measures to prevent this type of spill from being repeated. The plan needs to show how to clean up the spill if another one does occur.

Hazardous Products

- Keep products in original containers unless they are not resealable. If product is transferred to a new container, mark and label properly.
- Retain original labels and material safety data sheets. (See Petroleum and Hazardous Waste Management).

Disposal

If surplus product or a container must be disposed of, disposal must be done in accordance with State law. For local disposal information, contact your solid waste district, your local emergency planning committee or:

- In Missouri call 800-361-4827.
- In Kansas call 785-296-1667.

Maintenance, Inspections and Removal

- Inspect spill kits on a weekly basis and after each rainfall event that results in stormwater runoff. Inspect the spill kit anytime after material from the kit is utilized and note what material will need to be replaced.
- Maintain the appropriate contents of the spill kit as necessary. List contents of spill kit and attach it to the underside of the spill kit lid or some other readily accessible location. Include on the list the name and phone number of the person or company to contact to replace spill kit items.
- Remove this temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (See Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Spills are not handled properly, due to site personnel being unaware of spill kit or its location.	Educate all contractors and subcontractors as they begin work on the site. Ensure they know the location of the spill kits and how to use them.
Spill went undetected for a significant period or was not reported, caused by lack of education, lack of inspections or inattention.	Educate all site personnel that all spills are to be reported to the site superintendent immediately and the spill should be contained and cleaned up immediately. Ensure all site personnel are properly trained.

Emergency Numbers

- **In Missouri:** Contact the department's emergency spills hotline at 573-634-2436. More information about federal and Missouri laws and regulations is available on the Missouri Department of Natural Resources' Hazardous Waste Program webpage at www.dnr.mo.gov/env/hwp/lawsregs.htm or by calling 800-361-4827 or 573-751-3176
- **In Kansas:** Contact the department's 24-hour spill hotline at 785-296-1679. More information about Kansas laws and regulations is available on Kansas Department of Health and Environment webpage at www.kdheks.gov/waste or by calling 785-296-1600

Concrete Washout

Figure 6.21 Concrete washout pit with signage. Source: ABC's of BMP's, LLC

Concrete washout water is a pollutant due to the high pH solution of the wash water. Concrete wash water must be contained on a construction site, and the high pH water cannot be allowed to exit the site and enter a waterway. Alkalinity and chemical additives could be harmful to fish, stream bottom macro invertebrates and wildlife.

Washing waste concrete into waters of the state or in a location where it is likely to enter waters of the state, such as a drainage ditch, is prohibited by State Law and Regulations (644.051 RSMo, 10 CSR 20-6.010). As long as state and local regulations allow, a concrete washout area can be as little as a depressional area where the concrete truck drivers can empty their trucks after use. This may not be allowed in areas of karst topography where cracks and fissures in the rock would allow the wash water to enter ground water easily. Lined pits may need to be used or other containment systems.

Recommended Minimum Requirements

- Procedures for concrete washout should be documented and referenced in the stormwater pollution prevention plan. The site superintendent and field staff should be trained on the procedures and should ensure they are practiced. Construct the concrete washout area to contain the concrete washout so the solids may harden. In approved locations, locate the washout area so the liquid portion of the washout may soak into the ground. The hardened material can then be disposed of properly with construction waste.
- Concrete washout area(s) need to be clearly marked with proper signage, and locations must be shown on the site map within the stormwater pollution prevention plan. The concrete washout area or device should not be placed within 50 feet of a stream or within 100 feet of a classified stream, losing stream or sinkhole.

Construction

- Unless otherwise noted by state and local requirements, the concrete washout can be contained in an excavated pit or bermed area and then buried on-site a minimum of 24 inches below finished grade. The depth must provide a minimum of 24 inches of topsoil over the disposed concrete to allow proper vegetative growth in the area. In areas where concrete wash water is not allowed to be disposed of in the soil, a lined container must be used and after the concrete hardens and there is no liquid as a possible pollutant, the material can be disposed of properly along with other construction waste.
- The number of washout facilities installed should depend on the expected demand for storage capacity. On large sites with extensive concrete work, place washouts in multiple locations for ease of use.
- Install signage adjacent to each washout facility to inform concrete equipment operators to use the proper facilities. Also locations of the washout facilities should be shown on the stormwater pollution prevention plan site map.
- Locate concrete washout on-site at least 100 feet from storm drains, water bodies (wet or dry), open ditches, etc.

Maintenance, Inspections and Removal

- Concrete washout pits must be inspected on a weekly basis and after each rainfall event that results in stormwater runoff. Cover the washout area before predicted rainfall events to prevent overflows. When the concrete reaches 75 percent of the storage capacity of the pit, the hardened concrete must be disposed of in an approved manner.
- These devices are temporary and should be removed from the site after all concrete has been poured and they are no longer necessary.

Figure 6.22 EnviroSac Concrete Washout Bag - Source: Concrete Pump Supply, LLC.

Common Problems and Solutions

Problem	Solution
Concrete wash water is hosed into a storm drain or directly to the creek due to lack of education or inattention to compliance.	Ensure all employees understand it is illegal to wash concrete water into storm drains and streams.
Concrete trucks are hosed out onto areas considered “in need of rip-rap”, due to a lack of education about the environmental harm caused by concrete wash water, the use of current engineering methods preferred over rip-rap or the thoroughly regulated nature of washout disposal.	Ensure employees and concrete truck operators are well informed of the requirement to properly dispose of concrete washout. Discuss concrete management techniques with the concrete supplier before and after deliveries are made. Make sure concrete truck drivers are aware of the presence of concrete waste management facilities.
Concrete wash water is not contained within the system due to inadequately sized storage area.	Ensure the wash water does not enter a water body. Clean dried material out of the system as needed to ensure adequate storage, or enlarge the system so wash water is fully contained until dry.

Figure 6.23 Concrete washout system that can be installed and maintained by vendor. Source: Concrete Washout Systems Inc.

Dust Control and Air Emissions

Prohibited Open Burning Under State Regulations

In Missouri, any waste generated by a business, trade, industry, salvage or demolition operation cannot be burned without a permit issued by the Department of Natural Resources or its delegated local agency. Permits will only be considered for untreated wood wastes. Wastes that may not be burned include but are not limited to tires, rubber products, hazardous materials, styrofoam, plastics, petroleum based products, demolition waste, treated wood and any asbestos containing material.

Required Open Burning Permits

In Missouri, the open burning of certain trade wastes, primarily untreated wood wastes such as pallets or crates, throughout the state, and vegetation from land clearing operations in the Springfield-Greene County area and the Kansas City and St. Louis Metropolitan areas, may be permitted only when it can be shown open burning is the only feasible method of disposal and disposal is in the public interest. In the St. Louis nonattainment area, permits will not be issued unless it can be shown emissions from open burning would be less than any other waste management or disposal method. The open burning permit requires the facility, in most cases, to use an air curtain destructor.

For more information in Missouri contact the Missouri Department of Natural Resources at 800-361-4827, or:

- Contact your nearest Missouri Department of Natural Resources' Regional Office. Contact information located on the Web at www.dnr.mo.gov/regions/regions.htm.
- See *Facts on Open Burning Under Missouri Regulations* fact sheet at www.dnr.mo.gov/pubs/pub2047.pdf.
- Visit the Missouri Deparment of Natural Resources' Air Pollution Control Program website at www.dnr.mo.gov/env/apcp/publications.htm or call 573-751-4817.
- Visit the Missouri Department of Natural Resources' Solid Waste Management Program webpage at www.dnr.mo.gov/env/swmp/index.htm, or call 573-751-5401.

In Kansas, open burning is regulated by the Kansas Department of Health and Environment. Any open burning of tree and brush typically requires a permit. For more information:

- *Open Burning of Wood Waste* - Technical Guidance Document BAR2000-01.
- *Open Burning for Tree and Brush Sites* - Technical Guidance Document 2002.
- Technical Guidance Document (burning of waste).

For more information in Kansas, contact your Kansas Department of Health and Environment district office, or call 785-296-1550.

Note: Local governments may have stricter laws and policies regarding burning or disposal of wastes.

Dust Control Regulations

In Missouri, state regulation places limits on the amount of visible dust that can leave a property boundary. The general contractor is responsible for implementing control measures as necessary when handling, transporting or storing any material; construction, repair, cleaning or demolition of a building or its appurtenances; construction of use of a road, driveway or open area; or operation of a commercial or industrial installation without applying reasonable measures to prevent visible dust from leaving the property boundary.

For more information about this regulation:

- See 10 CSR 10-6.170 Restriction of Particulate Matter to the Ambient Air Beyond the Premises of Origin at www.sos.mo.gov/adrules/csr/current/10csr/10csr.asp.
- Visit the Missouri Deparment of Natural Resources' Air Pollution Control Program website at www.dnr.mo.gov/env/apcp/publications.htm or call 573-751-4817.

Dust control measures used to protect air quality must not cause a violation of the water quality standards, permit conditions or other regulations. For more information about dust control measures, see Surface Stabilization – Erosion Controls.

General Housekeeping Reminders

Some general reminders of information provided in this pollution prevention and good housekeeping section, include:

- An effort should be made to store only enough product to do the job. All materials stored on-site should be stored in a neat, orderly manner in their appropriate containers and, if applicable, under a roof or other enclosure.
- Products should be kept in their original containers with the original manufacturer's label. If a replacement container is used, it must be clearly labeled and the original label retained.
- Whenever possible, all of a product should be used up before disposing of the container.
- Manufacturer's recommendations for proper use and disposal of contents and containers must be followed. Refer to the Material Safety Data Sheets.
- The site superintendent should inspect daily to ensure proper usage, storage and disposal of materials.
- Fertilizers need to be applied only in the minimum amounts recommended by the manufacturer.
- All paint containers need to be tightly sealed and stored when not required for use. Excess paint may not be dumped into the storm sewer system but should be properly disposed of according to manufacturer's instructions, Material Safety Data Sheets and State and local regulations. (See Petroleum and Hazardous Waste Management). Non hazardous non bulk household products are allowed by regulation to be disposed of sanitary landfills. However, landfill operators may impose more stringent restrictions. Contact the local government for more information and refer to Solid Waste Management.
- Disposal of waste oil. If used oil has come into contact with hazardous materials, it is considered to be waste oil. It must be disposed of according to hazardous waste regulations. (See Petroleum and Hazardous Waste Management).
- Used oil (non hazardous) should be disposed of at the nearest used-oil recycling center. For more information, check with the local government and refer to the Missouri Solid Waste Management webpage at www.dnr.mo.gov/env/swmp/index.html or call 800-361-4827.
- Mudtracking is a common problem at construction sites. Refer to Site Preparation for proper exit pad installation and maintenance.

SECTION 3: SURFACE STABILIZATION - EROSION CONTROLS

Temporary Seeding

Figure 6.24 Temporary vegetation is a relatively inexpensive way to stabilize construction sites in a hurry. As grass grows, the roots hold soil in place and the plant protects the soil surface from raindrop impacts. Source: N. Klopfenstein, NRCS. St. Charles Co.

Practice Description

Temporary seeding is the establishment of fast-growing annual vegetation to provide economical erosion control for up to 6 months and reduce the amount of sediment moving off the site. Annual plants that germinate rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover.

This practice applies where short-lived vegetation needs to be established before final grading or in a season not suitable for permanent seeding.

Recommended Minimum Requirements

A qualified professional should specify plant materials, seeding rates and times of planting. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. To ensure emergence, vigorous growth of seedlings and continued plant growth, prepare the seedbed and add soil amendments according to soil tests. Protect the soil and seed with mulch or other erosion control until the vegetation is fully established to a density of 70 percent over the entire vegetated area.

Soil
Make sure there is a minimum of three inches of topsoil with a sufficient percentage of organic material to sustain vegetative growth.

Seedbed Preparation
Loosen soil to depth of 3-inches for broadcast seeding or drilling. If compacted, loosen soils for no till drilling. Avoid excessively wet conditions.

Amendments
Incorporate fertilizer and lime (if soil pH is less than 5.3) incorporated 3- to 6-inches into the soil. See Table 6.2.

Seed Quality
Use certified seed, tested within the past nine months.

Plants
Select recommended temporary erosion control plant species. Rate of application and seeding dates are listed in Tables 6.3 and 6.4.

Erosion Control
Cover the seeded area with approved mulching materials or other erosion control devices to protect the soil and seed until vegetation is fully established.

General
Inspect seeded areas 2 to 4 weeks after seeding for seed germination, vegetation establishment, erosion control and weed control. Repair and reseed as necessary.

Reseed
After six months if the site is not in permanent vegetation over the entire disturbed area to a density that impedes erosion.

Installation
Successful vegetative establishment is directly dependent on the nutrients in the soil. For optimum results, take soil samples from the top 6-inches in each area to be seeded. Submit samples to a soil testing laboratory for liming and fertilizer amendment recommendations.

Seedbed Preparation
- Seedbed preparation is essential for the seed to germinate and grow.
- For broadcast seeding and drilling, loosen the soil to a depth of approximately 3-inches.
- For no-till drilling, the soil surface does not need to be loosened unless the site has surface compaction.
- Use a disk, ripper, chisel, harrow or other acceptable tillage equipment to loosen compacted, hard or crusted soil surfaces. Avoid preparing the seedbed under excessively wet conditions.

Liming
- Acid soils with an extremely low pH can prevent seeding success. However, most of the recommended temporary vegetation is tolerant of low pH soils and will establish on all but the lowest pH soils.
- If soil pH in the region is known to be extremely low, conduct a soil pH test to determine if limestone is necessary for temporary seeding. Amend soils with lime according to information in Table 6.2. Soils with a pH above 7.0 should not be limed.

Table 6.2 Liming Requirements for Temporary Sites

pH Test	Plant Response	Recommended Application of Agricultural Limestone
Below 6.0	Poor growth	Lime according to soil test
6.0 - 6.5	Adequate growth	No lime recommended
Greater than 6.5	Optimum	No lime recommended

Fertilizer

- The soil will most likely be deficient in nutrients required for growth. A soil test will provide the best guide for the amount and types of fertilizer to apply for optimum plant growth.
- A general recommendation is to broadcast Ntirogen, Phosphorus and Potassium at 90 lbs./acre for areas receiving more than 30 inches of precipitation and 50 lbs./acre in areas receiving less than 30 inches of precipitation.

  For example, to compute the bulk pounds of product to use - For 100 pounds of a 10-10-10 fertilizer mix you have 10 percent or 10 pounds of actual Nitrogen, Phosphorus and Potassium. The remaining 70 percent or 70 pounds of product in the bag is inert material that improves application consistency. You would need to apply 900 pounds of product per acre to provide 90 pounds of actual Nitrogen per acre.
- For best results incorporate the fertilizer into the top 3- to 6-inches before seeding.

Seeding

- Apply seed evenly with a broadcast seeder, drill, cultipacker seeder or hydroseeder. Plant small grains no more than 1½ inches deep. Plant grasses and legumes no more than ½ inch deep.
- Prior to mulching, harrow, rake or drag a chain to lightly incorporate broadcast seed into the soil to enhance germination. Cover applied seed with mulch (See Mulching).

Table 6.3 Temporary Seeding Plant Materials and Minimum Seeding Rate *

Species	Seeding Rate		Plant Characteristics
	lbs. per Acre	lbs. per 1,000 ft.^{2}	
Oats	80 lbs.	2 lbs	Not cold tolerant, height up to 2 feet
Cereals: Rye/Wheat	90 / 120	2 / 2.5	Cold tolerant, height up to 3 feet, low pH tolerant
Millets, Sudangrass	45 / 60	1 / 1.25	Warm season annual, aggressive growth, height up to 5 feet
Annual Ryegrass	75	2	May be added to mix, not heat tolerant, height up to 16 inches
Annual Lespedeza** plus Tall Fescue	15 plus 45	0.5 plus 1	Warm season annual legume, makes own nitrogen, tolerated low pH

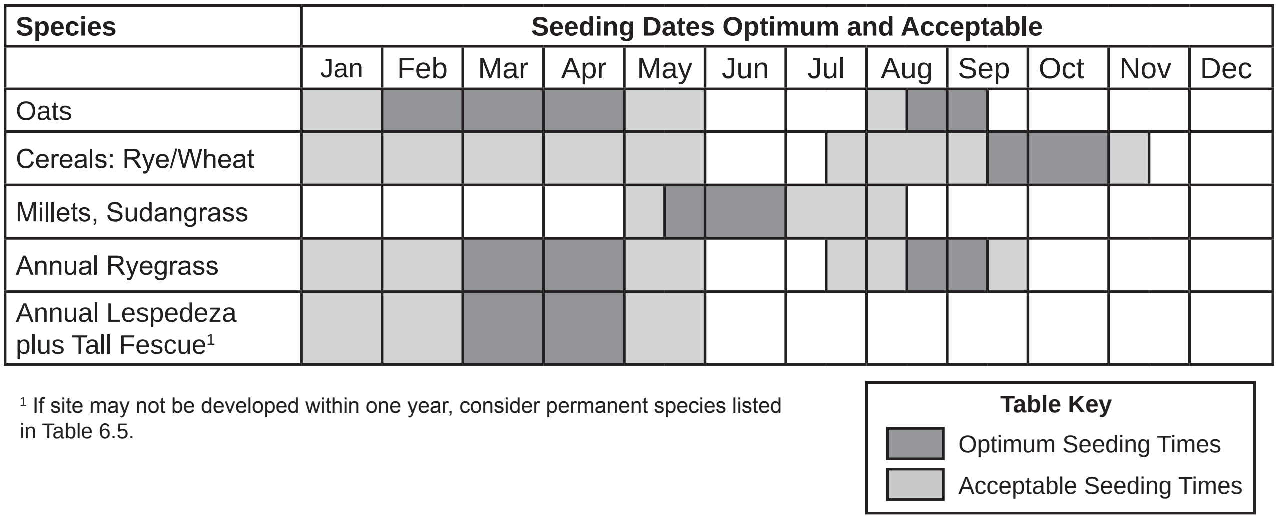
* In areas receiving less than 30 inches of precipitation, use 75 percent of these rates.

** If there is any possibility the seeding will be required to control erosion for more than one year, then consider the addition of fescue or another permanent species as part of a mixture when seeding.

Planting Dates

- Plant according to the design plan. In absence of a plan, choose a recommended temporary species or mixture appropriate for the season from Tables 6.3 and 6.4.
- Plant during optimum seeding dates if at all possible. Always use mulch or other erosion control practices to cover and protect seed and soil during vegetation establishment. Roll and cultipack broadcast seed for good soil-to-seed contact.
- Use high quality seed and for best results, use certified seed. When using uncertified seed, use the highest recommended seeding rate.

Table 6.4 Seeding Dates for Temporary Seeding



[1] If site may not be developed within one year, consider permanent species listed in Table 6.5.

Mulching

- Mulching conserves moisture and reduces erosion during seed germination and vegetation establishment.
- Evenly cover a minimum of 75 percent of the ground surface with mulch material specified in the design plan. Tack or tie down the mulch according to plan (See Mulching).

Construction Verification

Check materials and installation for compliance with specifications.

Maintenance and Inspection

- Check temporary seeding during each weekly inspection to monitor germination, growth and to see if stands are of adequate thickness (more than 70 percent density of the ground surface vegetation over the entire area to be stabilized). Stands should be uniform and dense for best results. Fertilize, reseed and mulch bare and sparse areas immediately to prevent erosion.
- Mowing is not recommended for cereals seeded alone. Cereals seeded with a grass can be mowed when height is greater than 12-inches. However, to prevent damage to grasses, do not mow shorter than 4-inches.
- Mow millets and sudangrass before height is greater than 6-inches to allow regrowth and continued erosion protection.
- Annual lespedeza and tall fescue may be mowed after height exceeds 8-inches. Do not mow shorter than 4-inches.
- Replant temporary or permanent vegetation within 12 months as annual plants die off and no longer provide erosion control (see Permanent Seeding). Consider no-till planting

where possible.

Common Problems and Solutions

Problem	Solution
Design specifications for seed variety, seeding dates or mulching cannot be met.	Substitutions may be required. Unapproved substitutions could lead to failure.
Vegetation is not sustainable as a permanent cover caused by a lack of topsoil resulting in a lack of organic material, nutrients and water holding capacity.	Add topsoil with a minimum of three percent organic material.
Poor seedling emergence and growth with erosion of the soil caused by inadequate seedbed preparation.	Repair gullies, prepare seedbed, fertilize, lime (if necessary), mulch and reseed.
Unsuitable choice of plant materials; resulting in poor germination or inadequate stand (less than 70 percent of the ground surface covered).	Choose plant materials appropriate for season, prepare seedbed and replant.
Poor or spotty stands of vegetative cover caused by inadequate mulching, washing away of the seed and erosion of the soil surface.	Poor plant vigor, yellow color and short height caused by a lack of nitrogen - add 50 lbs. of nitrogen fertilizer per acre. Do not apply over the top of existing plants from June 1 to Aug. 15 or on frozen ground.
Poor plant vigor, yellow color and short height caused by a lack of nitrogen.	Add 50 lbs. of nitrogen fertilizer per acre. Do not apply over the top of existing plants from June 1 to Aug. 15 or on frozen ground.
Dying plants caused by a lack of topsoil or soil compaction that limits root growth and water availability to plants.	Add organic material and loosen soil if reseeding is necessary or before seeding permanent vegetation.

Permanent Seeding

Figure 6.25 Permanent vegetation can be used to stabilize many structures, such as this grassed waterway, ensuring that runoff is relatively sediment-free.

Practice Description

Permanent seeding is the establishment of perennial vegetation on disturbed areas for periods longer than 12 months. Permanent vegetation provides economical long-term erosion control and helps prevent sediment from leaving the site. This practice is used when vegetation is desired to permanently stabilize the soil or if future phases of a construction site will remain dormant for a significant period of time after grading. It is necessary to protect earthen structures such as dikes, channels and embankments. Particular care is required to establish a good, thick cover of permanent grass.

Recommended Minimum Requirements

A qualified professional should specify plant materials, seeding rates and times prior to start of construction. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. To ensure germination and growth, prepare seedbed, add soil amendments according to soil tests, mulch all seeded areas and follow the seeding dates.

Seedbed Preparation

For broadcast seeding or drilling, loosen soil to depth of 3-inches. For no till drilling, loosen the soil if it’s compacted. Avoid excessively wet conditions.

Soil Amendments

Incorporate fertilizer and lime (if soil pH is less than 6.0) incorporated 3- to 6-inches into the soil.

Seed Quality
Use certified seed, tested within the past 9 months.

Planting Dates
Coordinate the construction schedule with planting dates appropriate for region and species (See Table 6.5).

Plants
Select from recommended erosion control plants (grass or grass/legume mixtures) as shown in Tables 6.5 and 6.6. Rate of application and seeding dates are shown in Tables 6.4, 6.7 and 6.8.

Mulch
Cover a minimum of 75 percent of the ground surface with approved material (See Mulching).

Inspection
Inspect seeded areas during each weekly inspection. Repair and reseed as necessary.

Installation
During final grading, take soil samples from the top 6-inches in each area to be seeded. Submit sample to a soil testing laboratory for liming and fertilizer recommendations.

Seedbed Preparation
- Seedbed preparation is essential for the seed to germinate and grow.
- For broadcast seeding and drilling, loosen the soil to a depth of approximately 3-inches.
- For no-till drilling, the soil surface does not need to be loosened unless the site has surface compaction.
- Loosen compacted, hard or crusted soil surfaces with a disk, ripper, chisel, harrow or other tillage equipment.
- Avoid preparing the seedbed under excessively wet conditions.

Liming
- Follow the recommendations resulting from the soil test. Apply ground agricultural limestone unless a soil test shows a pH of 6.5 or greater.
- Incorporate lime into the top 3- to 6-inches of soil.
- Do not add lime if the pH is 7.0 or greater.

Fertilizer
Remember: Phosphorus helps roots grow and develop to get the grass plants established. Nitrogen will only be taken up after the seed has germinated and the vegetation is growing. It may wash down stream if applied heavily during seeding.

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil test recommendations to local fertilizer dealer for bulk fertilizer blends. This may be more economical than bagged fertilizer.

For establishment and long-term growth, apply a complete fertilizer at rates recommended by soil tests or as specified in the design plan. In the absence of soil tests, use the following as a guide:

- A typical fertilizer blend for lawn grass mixes: Apply 10-24-18 which represents 10 percent of actual nitrogen – 24 percent of actual phosphorus and 18 percent of actual potassium within the fertilizer compound. If you had 100 pounds of a 10-24-18 blend you would have 10 pounds of actual nitrogen, 24 pounds of actual phosphorus and 18 pounds of actual potassium within the bag.

- A typical application rate of fertilizer for initial establishment of vegetation after seeding is approximately 1 pound of actual nitrogen per 1,000 square feet. With the 10-24-18 fertilizer this would require the application of approximately 435 pounds of this fertilizer mix per acre since there are 43,500 square feet in an acre. This fertilizer would also provide more than 2 pounds of phosphorus per acre.
- Incorporate lime and fertilizer to a depth of 3- to 6-inches by disking or chiseling on slopes of up to 3:1.
- Grade soil to a smooth firm surface to enhance rooting of seedlings and reduce rill erosion.
- Subsequent fertilization with an additional 2 pounds per 1,000 square feet of actual Nitrogen approximately one month after initial seeding will help grass growth after germination to achieve the density of vegetation to prevent or minimize erosion. A typical fertilizer for a second application once vegetation is established would be a 20-10-5 mix at 435 pounds of fertilizer per acre.

Plant Selection

If not specified in the design plan, choose a suitable species of grass or a grass/legume mixture from Tables 6.5 and 6.6 appropriate for the season. Consider site conditions including soils, plant characteristics, region of the state and desired level of maintenance. The species shown are adapted for lawns and erosion control. If there are questions on species selection and how they may be adapted in wildlife habitat or wetland applications, contact your local Natural Resources Conservation Service or Extension office.

Developing a Mixture

A pure stand of grass provides the best erosion control. The advantage of a grass/legume mix is the legume provides nitrogen to the grass and often grows during hotter and drier months when the grass is dormant. Usually one grass and one or two legumes is sufficient in a mixture. More grasses can be mixed together, but may be of little use. Refer to Tables 6.5 and 6.6 for information about each grass and legume to determine the correct species for your site.

Nurse Crops (Temporary or Annual Species)

Nurse crops are temporary grains that have one growing season such as wheat, rye and oats and are sometimes used in a seeding mixture. These annuals can reduce weeds, control erosion and provide protection to young seedlings until the perennial species become established.

Plant nurse crops about 1-inch deep. Most permanent grasses and legumes are sown 1/4 inch deep. Permanent seedings should not be planted deeper than ¼ to ½ inch.

Aesthetic Plantings

A wide variety of native forbs and grasses are available that add diversity and beauty to permanent plantings (e.g., switchgrass as an accent). Contact your local Natural Resources Conservation Service office for species selection and seeding rates.

Planting Dates

If seeding dates are not specified in the design plan or construction has not proceeded according to schedule, use the seeding calendar shown in Table 6.5.

Plant during optimum seeding dates if at all possible. Always use mulch or other erosion control measures to protect the seed and reduce erosion until the vegetation is established. For dormant seeding dates, broadcast seed and immediately roll and cultipack for good soil-to-seed contact.

If unable to seed according to schedule, use temporary seeding until the preferred date for permanent seeding.

Seeding Rates

If seeding rates are not specified in the design plan, use rates in Table 6.8 for grasses alone. Use rates in Table 6.9 for a grass or legume mixture. These rates are based on the poor growing conditions that typically exist on a development site, a need for dense growth and high germination rates.

For best results use certified seed. When using uncertified seed, use the highest recommended seeding rate. Higher seeding rates will not substitute for good seedbed preparation.

- Apply seed uniformly using a cyclone seeder, drop-type spreader, drill, cultipacker seeder or hydroseeder.
- When using a drill seeder, plant rye or other grains about 1-inch deep; plant grasses and legumes no more than ½ inch. Calibrate equipment in the field.
- Cover seed by raking, or dragging a chain, brush or mat. Then firm the soil lightly with a roller. Seed can also be covered with hydro-mulched wood fiber and tackifier or a rolled erosion control product.
- Legumes require inoculation with nitrogen-fixing bacteria to ensure good growth. Purchase inoculum from seed dealer and mix with seed prior to planting.

Table 6.5 Planting Dates Optimum and Acceptable* Planting Dates

Species	Seeding Dates Optimum and Acceptable											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turf Fescue		Acceptable	Acceptable / Optimum	Optimum / Acceptable	Acceptable			Acceptable / Optimum	Optimum / Acceptable	Acceptable		
Tall Fescue		Acceptable	Acceptable / Optimum	Optimum / Acceptable	Acceptable			Acceptable / Optimum	Optimum / Acceptable	Acceptable		
Kentucky Bluegrass		Acceptable	Acceptable / Optimum	Optimum / Acceptable	Acceptable			Acceptable / Optimum	Optimum / Acceptable	Acceptable		
Perennial Ryegrass		Acceptable	Acceptable / Optimum	Optimum / Acceptable	Acceptable			Acceptable / Optimum	Optimum / Acceptable	Acceptable		
Ryetop		Acceptable	Acceptable / Optimum	Optimum / Acceptable	Acceptable			Acceptable / Optimum	Optimum / Acceptable	Acceptable		
Reed Canary		Acceptable	Acceptable / Optimum	Optimum / Acceptable	Acceptable			Acceptable / Optimum	Optimum / Acceptable	Acceptable		
Bermuda - Common				— / Optimum	Optimum	Acceptable	Acceptable					
Bermuda- Hybrid				— / Optimum	Optimum	Acceptable	Acceptable					
Buffalograss[1]			Acceptable	Acceptable / Optimum	Optimum	Acceptable	Acceptable					
Zoysia2				— / Optimum	Optimum	Acceptable	Acceptable					
Birdsfood Trefoil	Acceptable	Acceptable	Acceptable / Optimum	Optimum / Acceptable								
Common Lespedeza			— / Optimum	Optimum / —								
Red Clover	Acceptable	Acceptable	Acceptable / Optimum	Optimum / Acceptable				Acceptable / Optimum	Optimum / —			
White Clover	Acceptable	Acceptable	Acceptable / Optimum	Optimum / Acceptable				— / Optimum	Optimum / —			
Wheat/Rye[3]	Acceptable	Optimum	Optimum	Optimum				Acceptable / Optimum	Optimum	Optimum	Optimum / Acceptable	
Oats[3,4]		Acceptable	Optimum	Optimum				Acceptable / Optimum	Optimum / —			

[1] Can also be sprigged.

[2] Usually sprigged. Space plugs every 6-, 8- or 12-inches; with 4,000, 2,250 or 1,000 sprigs/1000 ft^2 respectively.

[3] Check with your local Noxious Weed Department before planting.

[4] Nurse crop only.

[5] Provides a quick temporary cover or nurse crop even if planted in the fall.

Table Key

- Optimum Seeding Times
- * With Mulch Cover - Acceptable Seeding Times

Table 6.6 Plant Characteristics

Species		Kansas Adaptation	Missouri Adaptation	Maintenance	Fertility Needs	Establish-ment Ease
				L - M - H	L - M - H	P - M - G
Cool Season Grasses	Perennial ryegrass	E, C, W*	N, S	L	M	M
	Canada wildrye	E, C, W	N, S	M	L	G
	Tall fescue	E, C, W*	N, S	M	L - H	G
	Crested wheatgrass	E, C, W	N	M	L	M - G
	Kentucky bluegrass	E, C, W*	N, S	H	M - H[1]	M - G
	Bromegrass	E, C, W*	N, S	M	M - H[1]	M - G
	Redtop	S½ E	N, S	L	L	M
	Reed canary[1]	E, C, W*	N, S	H	L - M[3]	P
Warm Season Grasses	Common Bermuda	E, C, W*	S	L	L - M	M
	Hybrid Bermuda	E, C, W*	-	L	L - M	M
	Buffalograss[3]	E, C, W*	N, S	L	L	M
	Blue grama	E, C, W*	N, S	L	L	M
	Zoysia[4]	E, C, W*	-	M	M - H	M
	Sideoats grama	E, C, W*	N, S	M	L	G
	Little bluestem	E, C, W*	N, S	M	L	M
	Big bluestem	E, C, W*	N, S	M	L	M
	Indiangrass	E, C, W*	N, S	M	L	M
	Switchgrass	E, C, W*	N, S	M	L	M
Legumes[5]	Birdsfoot trefoil	E, C, W*	N, S	L	M	P - M
	Crownvetch	E, C, W*	N, S	M	M	P - M
	Annual lespedeza[6]	E, C, W*	N, S	M	M	P - M
	Red clover	E, C, W*	N, S	M	M	G
	White clover	E, C, W*	N, S	L	M	M - G
	Alfalfa	E, C, W*	N, S	M	L	P
Companion Crops/Cereal Grains	Wheat	E, C, W*			M	M
	Rye (cereal)	E, C, W*			M	M
	Oats	E, C, W*			M	M

* Adaptation limited to areas that receive additional moisture enhancement by irrigation, subirrigation or overland flow.

1 Will be high maintenance in lawn – type or low rainfall (<30”) settings.

2 Adapted to shorelines, wet or frequently flooded areas.

3 Responds well to fertilizer, but doesn’t necessarily require it.

4 Usually seeded, by can be sprigged.

5 Usually sprigged, plugged or sodded.

6 Legumes alone will not provide adequate erosion protection: use with a grass in a mixture.

7 Will reseed each year if not mowed until after seed shatter in September.

Table Key

L = low

M = moderate,

H = high.

P = poor,

G = good.

Table 6.7 Species Tolerance for Environmental Conditions

	Species	Tolerance				
		Shade	Drought	Flooding	Traffic	Soil Wetness
Cool Season Grasses	Perennial ryegrass	L	L	M	M	M
	Canada wildrye	M	M	L	M	P
	Tall fescue	M	M	M	M	P
	Crested wheatgrass	L	H	M	M	G
	Kentucky bluegrass	L	L	M	H	G
	Bromegrass	L	M	L	H	M
	Redtop	L	L	M	H	G
	Reed canary	L	M	H	H	G
Warm Season Grasses	Common Bermuda	L	H	H	H	M
	Hybrid Bermuda	L	H	H	H	M
	Buffalograss	L	H	H	H	G
	Blue grama	L	H	L	M	P
	Zoysia	L	H	M	H	P
	Sideoats grama	L	H	M	H	M
	Little bluestem	L	H	L	L	P
	Big bluestem	L	H	M	L	M
	Indiangrass	L	M	L	M	P
	Switchgrass	L	M	M	M	G
Legumes[5]	Birdsfoot trefoil	L	H	L	M	G
	Annual lespedeza	L	L	M	L	M
	Red clover	L	L	L	M	P
	White clover	L	L	L	H	M
	Alfalfa	L	L	L	L	P

1 Legumes alone will not provide adequate erosion protection: use with a grass in a mixture.

Table Key

L = Low
M = Moderate
H = High
P = Poor
G = Good

Table 6.8 Seeding Rates

Species		Kansas: Full Seeding Rate[1]	Missouri: Full Seeding Rate[1]
		lbs./acre (PLS)[2]	lbs./acre (PLS)[2]
Cool Season Grasses	Perennial ryegrass	150	150
	Canada wildrye	21	24
	Tall fescue	150	150
	Crested wheatgrass	20	16
	Kentucky bluegrass	120	120
	Bromegrass	100	100
	Redtop	8	8
	Reed canary[1]	40	40
Warm Season Grasses	Common Bermuda	2	4
	Hybrid Bermuda	20 bu./acre	-
	Buffalograss[3]	8 (grain)	8 (grain)
	Blue grama	3	6
	Zoysia[4]	20 bu./acre	-
	Sideoats grama	15	15
	Little bluestem	9	13
	Big bluestem	17	16
	Indiangrass	12.5	16
	Switchgrass	8	9
Legumes[5]	Birdsfoot trefoil	5	10
	Annual lespedeza[6]	14	16
	Red clover	8	12
	White clover	3	4
	Alfalfa	9	9
Companion Crops	Wheat	1 bu./acre	1 bu./acre
	Rye (cereal)	1 bu./acre	1 bu./acre
	Oats	1.5 bu./acre	1.5 bu./acre

1 Note: Rates based on typical construction site conditions where seedbed is normally less than ideal. Planned future use or specific site conditions may dictate an increase or a decrease in rates. Contact your local Natural Resources Conservation Service office or consulting agronomist for specific seeding rates within your county.

2 PLS or Pure Live Seed = the amount of seed guaranteed to grow.

3 Legumes alone will not provide adequate erosion protection: use with a grass in a mixture.

Table 6.9 Example Seeding Mixtures for Critical Area Seeding

Grass - Legume Mixture	Seeding Rate (PLS) *	
	lbs./1000 ft.^{2} ***	lbs./acre
Reed canarygrass / White clover	5 + 0.1	40 + 1
Reed canarygrass / Red clover	5 + 0.25	40 + 2
Tall fescue** / Birdsfoot trefoil	10 + 0.25	80 + 2
Tall fescue** / White clover	10 + 0.1	80 + 1
Tall fescue** / Lespedeza	10 + 0.5	80 + 4
Tall fescue** / Lespedeza / White clover	10 + 0.25 + 0.1	80 + 4 + 1
Tall fescue** / Red clover	10 + 0.25	80 + 2
Tall fescue** / Red clover / White clover	10 + 0.25 + 0.1	80 + 2 + 1
Kentucky bluegrass / White clover	3 + 0.1	25 + 1
Kentucky bluegrass / Red clover	3 + 0.25	25 + 2
Kentucky bluegrass / Birdsfoot trefoil	3 + 0.25	25 + 2
Kentucky bluegrass / Lespedeza	3 + 0.5	25 + 4
Perennial ryegrass / Red Clover	8 + 1	70 + 10
Perennial ryegrass / Birdsfoot trefoil	8 + 0.5	70 + 5
Perennial ryegrass / Lespedeza	8 + 3	70 + 25
Big bluestem / Indiangrass / Switchgrass / Sideoats grama / Western Wheatgrass	-	3.4 + 2.5 + 2 + 3 + 4
Wheat / Rye (as nursery crop)	1.5	60
Oats (as nursery crop)	0.75	30

* PLS or Pure Live Seed = the amount of seed guaranteed to grow. To calculate amount of bulk seed needed: Read seed tag and multiply % purity X % germination = % PLS; then divide lbs of PLS recommended by % PLS. Example: 30 lbs of Reed canary is needed to seed a 1 acre waterway; 90% pure X 90% germination = 81% PLS; 30 lbs PLS / .81 = 37 lbs. bulk seed needed.

** Turf fescue may be substituted for fescue at the same rates.

***Note: Use lbs. / 1,000 ft.^{2} rate to establish dense vegetation for lawns.

Erosion Control

- Mulching or a rolled erosion control product is recommended to conserve moisture, reduce erosion and protect the seed.
- Cover at least 75 percent of the area with approved mulch materials. Crimp, tack or tie down mulch with netting. Mulching is extremely important for successful seeding (See Mulching).

Construction Verification

Check materials and installation for compliance with specifications.

Maintenance and Inspection

- Inspect seeded areas weekly and after rain events. Check for erosion and seed wash out.
- Expect emergence of grasses and legumes within 28 days after seeding, with legumes following grasses.
- Check permanent seeding at each regular weekly inspection. Look for:
  - Germination.
  - Vigorous seedlings.
  - Uniform density with at least 70 percent of the ground surface covered.
  - Uniformity with nurse plants, legumes and grasses well intermixed.
  - Green, not yellow, leaves. Perennials should remain green throughout the summer, at least at the plant bases.

Reseeding

- Inspect seedings for die out for at least a year. Inspect the soil for erosional areas. To repair bare and sparse areas, fill gullies, refertilize, reseed and mulch. Consider no-till planting where possible.
- If stand is inadequate or plant cover is patchy, identify the cause of failure and take corrective action (e.g., choice of plant materials, lime and fertilizer quantities, poor seedbed preparation, lack of topsoil or weather.) If vegetation fails to grow, have the soil tested to determine whether pH is in the correct range or nutrient deficiency is a problem.
- Depending on stand conditions, repair with complete seedbed preparation, then overseed or reseed.
- If it's the wrong time of year to plant desired species, overseed with cereal grain or millets to thicken the stand until timing is right to plant perennials or use temporary seeding.

Fertilization

Satisfactory establishment may require refertilizing the stand in the second growing season.

- Do not fertilize cool season grasses in late May through July.
- Grass that looks yellow may be nitrogen deficient. An application of 500 lbs of 10-10-10 Nitrogen, Phosphorus, and Potassium per acre in early spring will help cool season grasses compete against weeds or grow more successfully.

Remember to convert actual pounds of nutrient needed when determining how many pounds of commercial fertilizer to buy.

- Do not use nitrogen fertilizer if stand contains more than 20 percent legumes.

Mowing

- Consider mowing after plants reach a height of 6- to 8-inches.
- Mow grasses tall, at least 3-inches in height and minimize compaction during mowing process.
- Monitor the late winter and early spring growth of nurse crops to be sure that they do not smother the permanent seeding. Mowing in April may reduce the competitiveness of the nurse crop and open the canopy to allow more sunlight to permanent seedlings that are beginning to grow.
- Vegetation on structural practices such as embankments and grass-lined channels need to be mowed only to prevent woody plants from invading.

Troubleshooting

Consult with design professional if the following occurs:

- Design specifications for seed variety, seeding dates or mulching cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Common Problems and Solutions

Problem	Solution
Poor stand of vegetation caused by inadequate topsoil.	Apply good topsoil with a minimum of 5 percent organic material and reseed.
Poor stand of vegetation caused by inadequate seedbed preparation.	Prepare well-tilled, limed and fertilized seedbed and reseed.
Vegetative stand failures caused by unsuitable choice of plant materials such as seeding Bermuda grass in the north or in the fall.	Select an appropriate species based on plant characteristics in Tables 6.8 and 6.9 and time of seeding.
Perennial vegetation overtaken by nurse crop with too high seeding mixture.	Limit rates to those shown in Table 6.9; eliminate old nurse crop, prepare seedbed and reseed.
Inadequate stand of vegetation caused by seeding at the wrong time of the year.	Consult Table 6.5 and reseed. If timing is not right, use temporary seeding to stabilize soil until preferred seeding dates.
Inadequate stand of vegetation, bare spots or eroded areas caused by inadequate mulching.	Prepare seedbed, reseed, cover seed evenly and tack or tie down mulch, especially on slopes, ridges and in channels (see Mulching).

Hydroseeding

Figure 6.26: Hydroseeding over matt armoring on a steep slope to promote vegetation growth and prevent erosion.
Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007

Hydroseeding is the application of a mixture of water, wood fiber (this could be paper or a 70/30 blend of wood fiber and paper), seed, fertilizer, and a soil stabilizer to temporarily and permanently protect exposed areas of soil from erosion due to wind, rain, and runoff. It is a way to establish grass where grass is the desired cover. This method is most often used in large-scale projects such as highway projects or steep slope areas where straw, sod and blankets are more challenging to use.

Hydroseeding is applied with a mechanical machine. Highway departments often use a boom machine with hoses that can shoot up to 100 feet or more, using soil stabilizers in the seed mix.

For most effective coverage, exposed soil surface should be loose (uncompacted) at time of application. Soil areas can be roughened by rolling the surface with a crimping or punching-type roller or by track walking to increase the soil surface area available for seeding. For best results, cover hydroseed layer (seed with soil stabilizer if used) with a mulch layer to keep applied seeds in place, retain soil moisture, and control soil temperature during seed establishment. The mulch acts as a blanket to protect the seed from wind and erosion.

Fertilizers should be included only when soil tests indicate a lack of adequate nutrients to establish and sustain the selected vegetation. However, there is much debate about whether starter fertilizers should be used at time of seeding. The important factor is to have adequate organic matter in the soil bed so that fertilizing is not necessary. Typically by time the seed

germinates and starts to develop a root system, about 25 percent of the fertilizer has leached out or washed away except when one is using a “cross-linked polymer” or so called “water retention polymer”. The other exception is when you are using a growth stimulator that will increase germination therefore allowing more of the starter fertilizer to still be in the soil. There are also other options to using fertilizers, such as guar, biostimulants and other root inoculants.

- The application of a soil binder may be necessary to further stabilize hydraulic mulch and seed to allow for germination and continued growth of vegetation. Soil binders in this case are sold as a tackifier and dust palliative all in one – not soil specific. The soil binder reacts with the soil, binding the mulch, seed, fertilizer, and other additives to the soil, holding it together until vegetation is established. Open weave matting can be applied before hydroseeding areas, especially in areas with steep slopes or sandy conditions, to provide additional structural support, creating a highly erosion-resistant surface to support vegetation establishment. There are also additive products available that have a fibrous material in them to create the same high performance bonding of soil, seed and mulch which is may be cheaper and more efficiently applied through the hydroseeder. See precautions on WCCs under Chemical Application for Turbidity Reduction.

Loading of soil binders and other additives should be done in accordance with machine manufacturer procedures. The hydroseed mix should be applied to the soil as soon as possible following the loading of additives. Otherwise, slurry may become too thick, and the machine could become clogged – wasting time, product and money. Straw, mulch, matting, or jute cover may be applied over the hydroseed application to further promote the vegetation and prevent erosion, but if too thick, the sun, oxygen and water cannot penetrate into the seed/soil.

Installation

- While construction activities are occurring.
- After construction activities are completed.
- Avoid application of hydroseed on existing vegetation, water bodies, sidewalks and roadways. Hydroseeding should not be used in areas where re-disturbance is expected within four to six weeks.
- In a manner that avoids overspray into water bodies, on sidewalks, and on roadways, where the products can end up polluting the water ways.
- Using appropriate hydroseeder equipment.
- Contact the local street department or the state transportation department for more information.

Inspected

- Inspect area at installation to ensure area is properly covered, and receiving waters are properly protected.
- Inspect area after a precipitation event and/or heavy wind for any removal of vegetation, mulch, or other stabilization material.

Maintenance Activities

- Repair coverage and re-apply hydroseed material as needed to maintain maximum protection against erosion.
- If plant seeds fail to germinate, or established plants die, area must be re-seeded. Consult with product distributor or SWPPP preparer for troubleshooting application problems.
- If the desired permanent seeding type is different from the temporary seed, temporary seeding may have to be removed prior to the application of permanent seeding

Common Problems and Solutions

Problem	Solution
In some cases, grass has low germination percentage due to poor contact with soil.	Additives used in hydroseeding can enhance germination and root development, but cautions should be taken to ensure the additives do not make their way to the drainage system.
Hydroseeding application does not cover soil completely and erosion occurs.	Ensure initial application of hydroseeding is done in two directions for proper coverage. Ensure proper products and application rates are used correctly.

Mulch and Hydromulch

Figure 6.27 It takes about two tons per acre of straw mulch to cover at least 75 percent of the ground surface. To prevent erosion and provide the best microclimate for seed establishment, straw mulch should be physically anchored (crimped) or tied down with a tackifier.

Practice Description

Mulch and hydromulch are the application of plant residues such as straw or other suitable materials to the soil surface to reduce erosion. Mulch protects the soil surface from the erosive force of raindrop impact and reduces the velocity of overland flow. It helps seedlings germinate and grow by conserving moisture, protecting against temperature extremes and controlling weeds. Mulch also maintains the infiltration capacity of the soil.

Hydraulic mulch consists of applying a mixture of shredded paper, wood fiber or a hydraulic matrix and a stabilizing emulsion or tackifier with hydroseeding equipment, which temporarily protects exposed soil from erosion by raindrop impact or wind.

Mulch should always be applied to seeded areas to help establish plant cover and protect the seed during establishment.

Recommended Minimum Requirements

Prior to start of construction, mulch requirements should be determined by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process..

Material

As specified in the approved site plan. If not specified, select from mulch materials listed in Table 6.10. Base the choice upon soils, slope steepness and length, flow conditions and time of year (See Figure 6.29).

Coverage
At least 75 percent of the soil surface.

Anchoring
Anchor the light materials, such as hay and straw mechanically using a crimping disc or with hydraulic tackifiers or netting. Heavy material mulches such as wood chips will not require anchoring unless on slopes of 4:1 or greater.

Installation
Site Preparation
- Divert runoff water away from areas above the site that will be mulched.
- Remove large dirt clods, stumps, roots and other debris from the construction area.
- Grade area as needed to permit the use of equipment for seeding, mulching and maintenance. Shape area so it is relatively smooth.
- If the area will be seeded, follow seeding specifications in the design plan (See Temporary and Permanent Seeding) and apply mulch immediately after seeding.

Mulching
Spread straw or cereal grain mulch uniformly over the area with a power blower or by hand. No more than 25 percent of the ground surface should be visible after spreading.

Apply at the rates shown in Table 6.10. Use higher rates for steep slopes and other erosive areas.

Anchor straw mulch by one of the following methods:
- Crimp with a weighted, straight, notched disc or a mulch anchoring tool to punch the straw into the soil.
- Tack with a liquid tackifier designed to hold mulch in place. Use suitable spray equipment and follow manufacturer's recommendations.
- Cover with netting, using a degradable natural or synthetic mesh to hold mulch materials in more erosive areas. Anchor the netting according to manufacturer's specifications (See Erosion Control Blankets).
- Anchor wood cellulose mulch with a liquid tackifier.

Figure 6.28 shows straw that that has been crimped with a disc blade as in Figure 6.27. Notice when the blade cuts the straw into the soil to anchor it, some of the straw may become vertical and thereby exposing the soil surface to raindrop impact. The vertical straw acts more like a sediment control and you lose some erosion protection. This can be remedied by increasing the amount of mulch used to 3 or 4 tons per acre if crimping will take place. Table 6.10 provides the application rates of different mulch materials.

Use heavy natural nets without additional mulch, synthetic netting with additional mulch or erosion control mats/blankets to control erosion on steep slopes and in areas needing a higher degree of protection such as waterways, swales and diversion channels. These commercial materials vary greatly in longevity, strength, heaviness and the rate of water flow they can handle.

Install netting and mats/blankets according to manufacturer's specifications making sure materials are properly anchored (See Erosion Control Blankets).

Construction Verification
Check materials and installation for compliance with specifications.

Figure 6.27 Crimping disc. Source: ABCs of BMPs, LLC.


Figure 6.28 Crimped straw. Source: ABCs of BMPs, LLC.

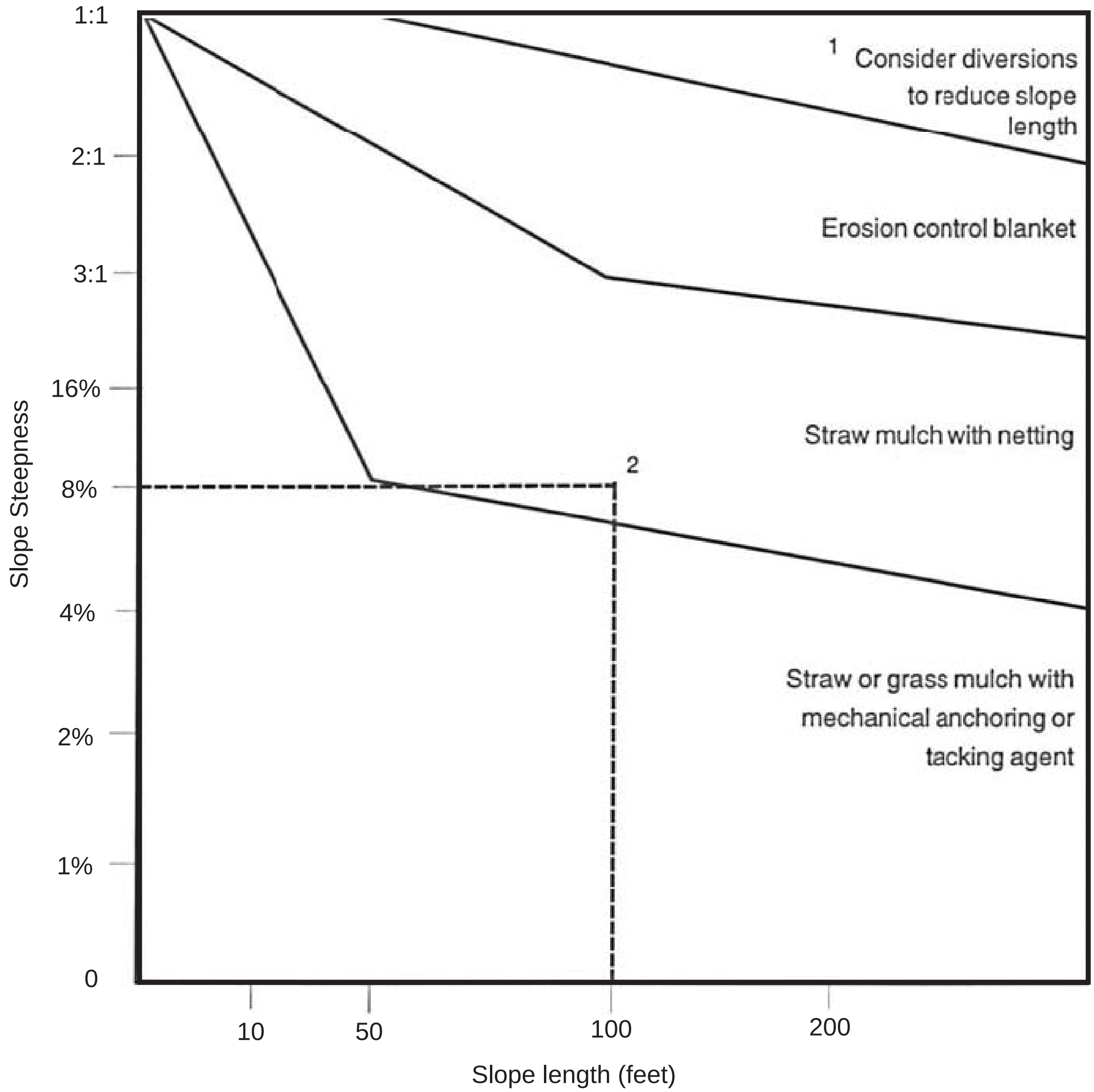
Table 6.10 Typical Mulching Materials and Application Rates

	Rate per Acre	Requirements	Installation Uses	Longevity
Organic Mulches				
Straw	3,000 - 4,500 lb./acre	Dry, unchopped, unweathered; free of weed seeds and rot	Spread by hand or machine, 1.5 to 2.5 inches deep; must be crimped or tacked with vegetative overspray	2 - 4 weeks
Paper, wood fiber, recycled newsprint	2,000 lb./acre	Can use paper on flatter areas, increase percentage of wood fiber as slopes steepen	To be used with hydroseeder, refer to seeding chart for dates to seed	2 - 4 months
Stabilized Fiber Matrix	Refer to manufacturers recommendations - usually 1,500 - 3,000 lb./acre	Typically requires wood fiber mulch to reduce rainfall impact. Requires 24-hour cure time-not used in concentrated flows	To be used on more erodible slopes, molecularly binds soil particles for improved erosion protection, can be used without seed for temporary soil protection	4 - 5 months
Bonded Fiber Matrix	Refer to manufacturers recommendations - 3,000 - 4,000 lb./acre depending on steepness of slope	24-hour cure time, can be used on slopes as steep as 2:1, not used in concentrated flows	Does not require smooth finish grade, can be used in soils with high rock content, can be used with out seed for temporary soil protection	4 - 6 months
Flexible Growth Medium	Refer to manufacturers recommendations - 3,000 - 4,500 lb./acre depending on steepness of slope	No cure time, can be used on slopes steeper than 1:1, not used in concentrated flows without TRM combination	Does not require smooth finish grade, can be used in soils with high rock content, molecularly binds soil particles, equivalent to short term erosion control blankets in many cases	up to 1 year
Wood Chips	10-20 Tons	Air dry, add nitrogen fertilizer	Apply with blower…	6 - 9 months
Bark	35 cubic yds.	Air dry…	Apply with…	6 - 9 months
Tackifiers				
Mulch tackifiers	Rates vary-refer to manufacturers specifications	Powders, liquids, crystals, etc.; most are water soluble	Mix with organic mulches to hold together, heavier rates required for steeper slopes	1 - 3 months
Straw Tackifiers	750 lb./acre	Recycled newsprint with tackifier	Spray overtop of vegetative mulching to hold together for extended time.	1 - 3 months
Soil Binders				
Chemical and Biodegradable products: Many Trade Names	Follow manufacturers specifications	Use for temporary and longer term stabilization of non-vegetative soils	Some may be harmful to plant growth, check manufacturers recommendations for seeding limitations	30 days to 6 months depending upon rate

Source: ASP, Enterprises, 2009

* See Temporary Erosion Control Blanket section for nettings and mats.

**Enlist the assistance of a Certified Professional in Erosion and Sediment Control for specific recommendations.



[1] For slopes steeper than 1:1, consider building a diversion above slope to divert water.

[2] Example: An 8 percent slope 100’ long requires a straw mulch with netting.

[*] Recommendations for specific sites may vary depending upon local conditions.

Figure 6.29 General mulch recommendations to protect from splash and sheet flow. Source: Adapted from *Minnesota Protecting Water Quality in Urban Areas,1991*

Troubleshooting

Consult with a qualified design professional if any of the following occur:

- Variations in topography on-site indicate the mulching materials will not function as intended; changes in the plan may be needed.
- Design specifications for mulching materials or seeding requirements cannot be met; substitution may be required. Unapproved substitutions could result in erosion or seeding failure.

Maintenance and Inspection

Inspect all mulched areas on a weekly basis and after rainstorms for erosion and damage to the mulch. Repair promptly and restore to original condition. Continue inspections until vegetation is well established. Keep mower height high if plastic netting is used to prevent netting from wrapping around mower blades or shaft.

Common Problems and Solutions

Problem	Solution
Erosion, washout and poor plant establishment.	Check for proper topsoil, repair eroded surface, reseed, remulch and anchor mulch.
Mulch is lost to wind or stormwater runoff.	Reapply mulch and anchor by crimping, netting or tacking.
Mulch not anchored in channel; resulting in channel bottom eroding	Repair damage, replace mulch and anchor or install appropriate turf reinforcement mat channel liner.
Mulch deteriorates before plant establishment.	Check for proper topsoil, reapply mulch, do not hydromulch in winter.

Erosion Control Blankets

Figure 6.30 Follow manufacturer's recommendations to successfully install erosion control blankets or matting. The manufacturer of this high velocity blanket called for stapling every two feet and a check slot wherever two sections were joined. This blanket was used to protect soil and establish grass in a waterway on the August Busch Memorial Conservation Area

Practice Description

Erosion control blankets are used to aid in controlling erosion on critical areas by providing a protective cover made of straw, jute, wood or other plant fibers; plastic, nylon, paper or cotton. This practice is best used on slopes and channels where the erosion hazard is high and plant growth is likely to be slow to provide adequate protective cover for the seed and soil until germination. Erosion control blankets are typically used as an alternative to mulching but are also used to provide structural erosion protection.

Some important factors in the choice of a blanket are: soil conditions, steepness of slope, length of slope, type and duration of protection required to establish desired vegetation, and probable sheer stress. (See Compost for compost blanket considerations.)

Recommended Minimum Requirements

Prior to the start of construction, the application of erosion control blankets should be designed by a qualified professional and plans and specifications should be available to field personnel. The field inspector should verify that installation is in accordance with the plans and specifications.

Numerous products designed to control erosion are available. Product installation procedures for manufactured erosion control blanket products should always be available from the manufacturer. Tables 6.11 and 6.12 list some of the more common temporary and permanent products available.

Table 6.11 Types of Temporary Erosion Control Blankets

ULTRA SHORT-TERM - Typical three month functional longevity						
Type	**Product Description**	**Material Composition**	**Slope Applications***		**Channel Applications***	**Minimum**
			Maximum Gradient	**C Factor[2, 5]**	**Max. Shear Stress[3, 4, 6]**	**Tensile Strength[1]**
1.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	< 0.1 @ 5:1	0.25 lb./ft.^{2} (12 Pa)	5 lb./ft. (0.073 kN/m)
1.B	Netless Rolled Erosion Control Blankets	Natural or polymer fibers mechanically interlocked or chemically adhered together to form a RECP.	4:1 (H:V)	< 0.1 @ 4:1	0.5 lb./ft.^{2} (24 Pa)	5 lb./ft (0.073 kN/m)
1.C	Single-net Erosion Control Blankets and Open Weave Textiles	Processed degradable natural or polymer fibers mechanically bound together by a single rapidly degrading, synthetic or natural fiber netting or an open weave textile of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	< 0.15 @ 3:1	1.5 lb./ft.^{2} (72 Pa)	50 lb./ft. (0.73 kN/m)
1.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two rapidly degrading, synthetic or natural fiber nettings.	2:1 (H:V)	< 0.2 @ 2:1	1.75 lb./ft.^{2} (84 Pa)	75 lb./ft. (1.09 kN/m)
SHORT-TERM - Typical 12 month functional longevity						
2.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegrad-able natural fiber netting.	5:1 (H:V)	< 0.1 @ 5:1	0.25 lb./ft.^{2} (12 Pa)	5 lb./ft. (0.073 kN/m)
2.B	Netless Rolled Erosion Control Blankets	Natural and/or polymer fibers mechanically interlocked or chemically adhered together to form a RECP.	4:1 (H:V)	< 0.1 @ 4:1	0.5 lb./ft.^{2} (24 Pa)	5 lb./ft. (0.073 kN/m)
2.C	Single-net Erosion Control Blankets and Open Weave Textiles	An erosion control blanket composed of processed degradable natural or polymer fibers mechanically bound together by a single degradable synthetic or natural fiber netting to form a continuous matrix or an open weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	< 0.15 @ 3:1	1.5 lb./ft.^{2} (72 Pa)	50 lb./ft. (0.73 kN/m)
2.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two degradable, synthetic or natural fiber nettings.	2:1 (H:V)	< 0.2 @ 2:1	1.75 lb./ft.^{2} (84 Pa)	75 lb./ft. (1.09 kN/m)

EXTENDED-TERM - Typical 24 month functional longevity.						
3.A	Mulch Control Nets	A slow degrading synthetic mesh or woven natural fiber netting.	5:1 (H:V)	< 0.10 @ 5:1	0.25 lb./ft.^{2} (12 Pa)	25 lb./ft. (0.36 kN/m)
3.B	Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1.5:1 (H:V)	< 0.25 @ 1.5:1	2.00 lb./ft.^{2} (96 Pa)	100 lb./ft. (1.45 kN/m)
LONG-TERM - Typical 36 month functional longevity.						
4	Erosion Control Blankets and Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1:1 (H:V)	< 0.25 @ 1:1	2.25 lb./ft.^{2} (108 Pa)	125 lb./ft. (1.82 kN/m)

Source: *Erosion Control Technology Council.*

* "C" factor and shear stress for Types 1.A., 2.A. and 3.A mulch control nettings must be obtained with netting used in conjunction with pre-applied mulch material.

[1] Minimum Average Roll Values, Machine direction using ECTC Mod. ASTM D 5035.

[2] "C" Factor calculated as ratio of soil loss from RECP protected slope (tested at specified or greater gradient, h:v) to ratio of soil loss from unprotected (control) plot in large-scale testing.

[3] Required minimum shear stress RECP (unvegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in) soil loss) during a 30-minute flow event in large-scale testing.

[4] The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coeffecients in the range of 0.01 - 0.05.

[5] Acceptable large-scale test methods may include ASTM D6459,or other independent testing deemed acceptable by the engineer.

[6] Per the engineers discretion. Recommended acceptable large-scale testing protocol may include ASTM D6460, or other independent testing deemed acceptable by the engineer.

TABLE 6.12 Types of Temporary Erosion Control Blankets - For applications where vegetation alone will not sustain expected flow conditionsor provide sufficient long-term erosion protection.

PERMANENT[1] - All categories of TRMs must have a minimum thickness of 0.25 inches (6.35 mm) per ASTM D 6525 and U.V. stability of 80 percent per ASTM D 4355 (500 hours exposure).					
Type	**Product Description**	**Material Composition**	**Slope Applications**	**Channel Applications***	**Minimum**
			Maximum Gradient	**Max. Shear Stress[4, 6]**	**Tensile Strength[2, 3]**
5.A	Turf Reinforcement Mat	Turf Reinforcement Mat – A rolled erosion control product composed of non-degradable synthetic fibers, filaments, nets, wire mesh or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. Mats that may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. Note: Mats are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated.	0.5:1 (H:V)	6.0 lbs/ft^2 (288 Pa)	125 lbs/ft (1.82 kN/m)
5.B	Turf Reinforcement Mat		0.5:1 (H:V)	8.0 lbs/ft^2 (384 Pa)	150 lbs/ft (2.19 kN/m)
5.C	Turf Reinforcement Mat		0.5:1 (H:V)	10.0 lbs/ft^2 (480 Pa)	175 lbs/ft (2.55 kN/m)

Source: *Erosion Control Technology Council.*

[1] For mats containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

[2] Minimum Average Roll Values, machine direction only for tensile strength determination using ASTM D6818 (Supercedes Mod. ASTM D5035 for RECPs)

[3] Field conditions with high loading or high survivability requirements may warrant the use of a mat with a tensile strength of 44 kN/m (3,000 lb./ft.) or greater.

[4] Required minimum shear stress mat (fully vegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in.) soil loss) during a 30-minute flow event in large scale testing.

[5] Acceptable large-scale testing protocol may include ASTM D6460, or other independent testing deemed acceptable by the engineer.

Construction
Site Preparation

- Grade the site in accordance with the approved design to a smooth and uniform surface, free of debris.
- Add and incorporate topsoil where needed.
- Make sure seed bed is firm yet friable.
- Seed and fertilize as shown on the design plan.

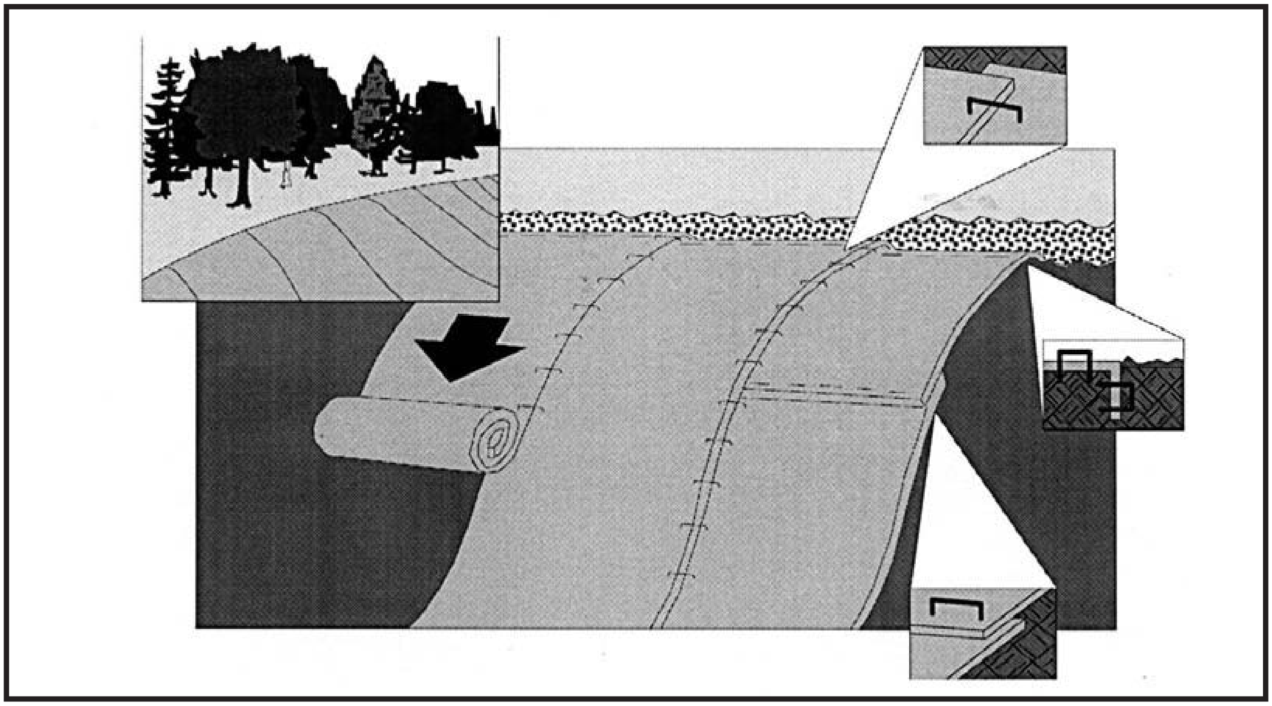


Figure 6.31 Typical installation of erosion control blankets on a slope - Consult manufacturer for recommendations on proper installation of staple patterns, overlap and keying edges.

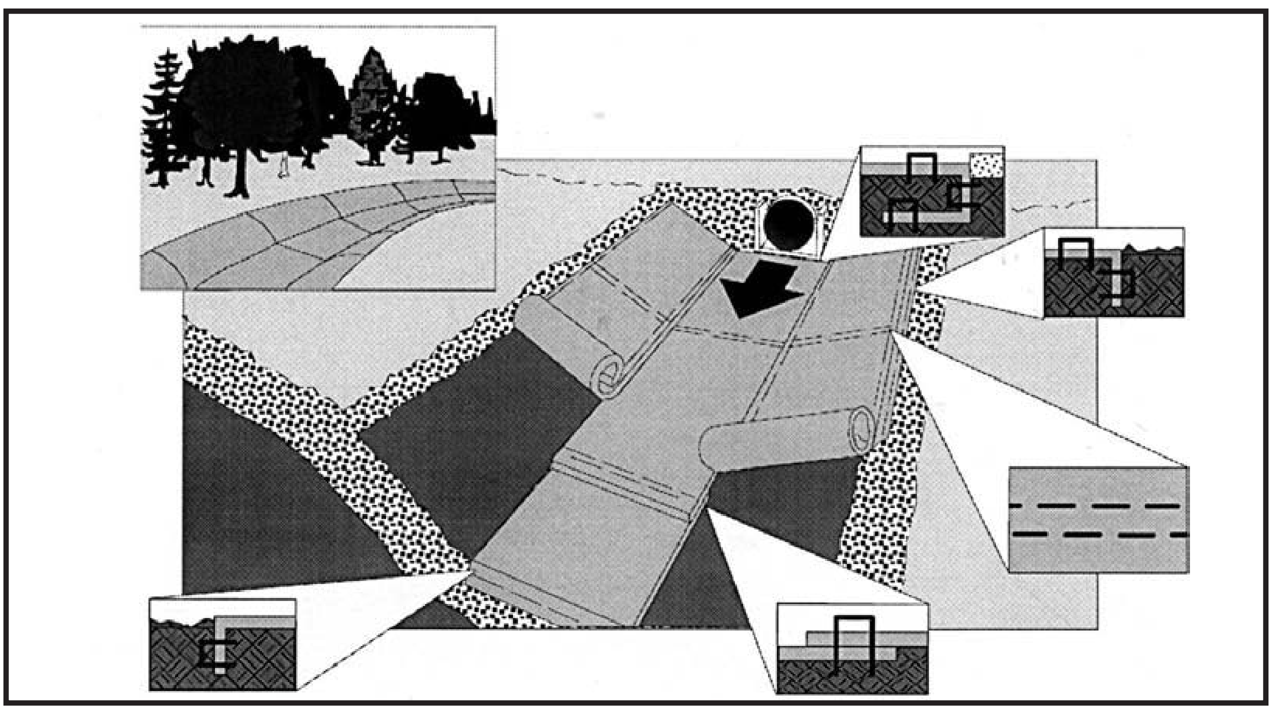


Figure 6.32 Typical installation of erosion control blankets in a channel - Consult manufacturer for recommendations on proper installation of staple patterns, overlap and keying edges.

Erosion Control Blankets

Blanket Installation

Install erosion control products in accordance with the manufacturer's recommendations and specifications, including check slots and stapling materials.

Anchor product so a continuous, firm contact (no tenting) with the soil surface/seed bed is maintained. Soil must be fine graded with no clods.

Note: Failure to do the above could result in soil erosion, which would require regrading and reseeding.

Construction Verification

Check finished grade, dimensions and staple spacing of erosion control blankets. Check materials for compliance with specifications.

- Movement of the blanket or erosion under the blanket is observed.
- Variations in topography on-site indicate erosion control mat will not function as intended; changes in the plan may be needed, or a blanket with a shorter or longer life may be needed.
- Design specifications for seed variety, seeding dates or erosion control materials cannot be met; substitution may be required. Unapproved substitutions could result in failure to establish vegetation.

Maintenance, Inspection and Removal

Inspect weekly and after storm events, until vegetation is established, for erosion or undermining beneath the blankets. If any area shows erosion, pull back that portion of the blanket, add tamped soil and reseed; then resecure the blankets.

If blankets become dislocated or damaged, repair or replace and resecure immediately.

Although some erosion control blankets are temporary, they are left in place to decompose and are not to be removed prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Surface water flows under rather than over the blanket, causing erosion. This may be caused by poor contact between soil and the erosion control blanket.	Smooth grade or remove large clods and retrench or reanchor to direct water over blanket.
Tenting (air pockets under blanket), blanket movement or displacement is caused by blanket inadequately or improperly stapled.	Reinstall and ensure blanket is properly anchored.
Blanket or slope failure caused by unstable slope.	Determine cause of slope failure, stabilize slope and reinstall blanket.

Dust Control

Figure 6.33 Spraying water is effective for dust control on haul roads, although it must be frequently repeated during hot days or heavy traffic periods. Source: C. Rahm, NRCS. St. Charles Co.

Dust Control

In Missouri, the contractor is required by State law to control fugitive dust blown from the site. Kansas does not have specific regulations for fugitive dust emissions; however, the Kansas Department of Health and Environment encourages contractors to implement measures to reduce such emissions. Dust can be minimized by stabilizing areas with mulch as soon as possible. Provide watering in unstabilized areas. Contact Missouri Department of Natural Resources or Kansas Department of Health and Environment for guidance.

Practice Description

Dust control includes a wide range of techniques that reduce movement of wind-borne soil particles (dust) from disturbed soil surfaces. This practice applies to construction routes and other disturbed areas where on-site and off-site damage or hazards may occur if dust is not controlled.

Recommended Minimum Requirements

Dust control measures should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. Whenever possible, leave undisturbed vegetated buffer areas between graded areas.

Scheduling

Plan and schedule construction operations so the smallest area is disturbed at one time.

Erosion Control

Install surface stabilization measures immediately after completing land grading.

Construction

Any combination of the following may be used to help reduce dust and air pollution at a construction site.

Vegetative Cover

For areas not subjected to traffic, vegetation provides the most practical method of dust control (See Temporary or Permanent Seeding).

Sprinkling

The site can be sprinkled with water until the surface is moist. This practice is effective for dust control on haul roads or other traffic routes, but constant repetition is required for effective control.

Soil Stabilizers and Binders

Soil stabilizers are polymers that bind the soil particles together so they are less likely to be transported in the air from the energy of the wind.

Limitations

- Soil binders are temporary in nature and may need reapplication.
- Soil binders require a minimum curing time until fully effective, as prescribed by the manufacturer, which may be 24 hours or longer. Soil binders may need reapplication after a storm event.
- Soil binders will generally experience spot failures during heavy rainfall events. If runoff penetrates the soil at the top of a slope treated with a soil binder, it is likely the runoff will undercut the stabilized soil layer and discharge at a point further down slope.
- Some soil binders do not hold up to pedestrian or vehicular traffic across treated areas. Consult manufacturers' representatives for specific applications and limitations of materials.
- Soil binders may not penetrate soil surfaces made up primarily of silt and clay, particularly when compacted. Some soil binders may not perform well with low relative humidity. Under rainy conditions, some agents may become slippery or leach out of the soil.
- Soil binders may not cure if low temperatures occur within 24 hours of application.

General Considerations

- Site-specific soil types will dictate appropriate soil binders to be used.
- A soil binder must be environmentally benign (non-toxic to plant and animal life), easy to apply, easy to maintain, economical and shall not stain paved or painted surfaces.
- Some soil binders are compatible with existing vegetation.
- Performance of soil binders depends on temperature, humidity and traffic across treated areas.
- Avoid over-spray onto the traveled way, sidewalks, lined drainage channels, and existing vegetation.

Dust Control
Water clarifying compounds may be used on mineral soils for dust control. Traffic must be kept off treated areas to prevent the product from becoming ineffective. The manufacturer or supplier shall provide written application methods for the water clarifying compounds and mixtures. The application method shall ensure uniform coverage to the target and avoid drift to non-target areas including waters of the state. The manufacturer or supplier shall also provide written instructions to ensure proper safety, storage and mixing of the product.

Mulching
This practice offers a fast and effective means of controlling dust when properly applied. Use binders or tackifiers to tack organic mulches (See Mulch and Hydromulch). Mulching is not recommended for areas with heavy traffic.

Barriers
Board fences placed perpendicular to the prevailing winds at intervals of 15 times the barrier height can control blowing soil. In areas of known dust problems, windbreak vegetation should be preserved.

If the following materials or any other chemicals are used for dust control, contact the Missouri Department of Natural Resources, Water Pollution Control Program, or the Kansas Department of Health and Environment for permit requirements.

- Calcium Chloride - This material is best used on road surfaces. It can be applied by a mechanical spreader at a rate that keeps the surface moist.

Note: This method may cause restrictions for vegetation establishment.

Maintenance and Inspection
- Maintain dust control measures continuously throughout dry weather periods until all disturbed areas have been stabilized.
- If using a soil binder, it may need to be reapplied for proper maintenance.
- High traffic areas shall be inspected daily, and lower traffic areas shall be inspected weekly.
- After any rainfall event, the permittee is responsible for maintaining all slopes to prevent erosion.

Troubleshooting
Consult with a qualified professional if the following occurs:
- Spray-on adhesives are specified. A permit may be needed.

Common Problems and Solutions

Problem	Solution
Dry soils and increase in dust problems caused by drought conditions.	Use greater precautions during these periods.

Sodding

Figure 6.34 A team is laying sod strips so the seams are not aligned and the ends and sides are against each other to reduce drying out of the roots. Source: N. Klopfenstein, NRCS. St. Charles Co.

Practice Description

Sodding is the use of a vegetative cover that includes both the grass plants as well as an established root system to provide immediate erosion control in disturbed areas. Sodding is well suited for stabilizing erodible areas such as grass-lined channels, stormwater detention basins, diversions, swales, slopes and buffer strips.

Recommended Minimum Requirements

Prior to start of installation, plant materials and amendments should be specified by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process..

Plant Selection

Select high quality, healthy, moist, fresh sod. Select a variety that is well-adapted to the region, supports its intended use, and is appropriate for the desired level of maintenance.

Soil Amendments

Fertilizer and lime (if soil pH is less than 6.0) incorporated to a depth of 3- to 6-inches into the soil.

Soil Surface

Clear of clods, rocks, etc.; smooth and firm; not compacted clay or pesticide-treated soil.

Irrigation
Temporary irrigation is required to ensure rooting and plant establishement.

Timing
Anytime of the year, except when the soil is frozen. Check with local sod farms for availability.

Installation
Soil supplied nutrients are critical to sod establishment and continued plant growth. Test soil for nutrients and pH. Soil testing can be done at University Extension offices and private labs.

Site Preparation
Apply amendments according to soil test recommendations.
In the absence of a soil analysis, apply fertilizer amendments at the following maximum rates:

- Fertilizer: Apply 500 pounds of a 10-10-10 Nitrogen, Phosphorus and Potassium.
- Consult a qualified professional who specializes in soils and soil amendments.

Apply ground agricultural limestone unless a soil test shows a pH of 6.0 or greater.
If soil test recommendations are not available and soil pH is less than 6.0, use:

- Ground agricultural limestone: 20 lb. ENM or ECC* /1,000 ft^2 or 800 lb. ENM or ECC/acre (approx. 2 tons/acre). Missouri state agricultural lime laws require ag lime be sold as units of Equivalent Neutralizing Material (ENM)/ton. For example, soil test requires 800 lbs ENM and lime producer's material tests at 400 lb. ENM. 800/400 = 2 tons to be applied. See MU Guide #9107 for details. In Kansas, ECC (Effective Calcium Carbonate) = ENM. (See Glossary for definition.)
- Incorporate amendments to depth of 4- to 6-inches with a disk or chisel plow.
- Rake or harrow to achieve a smooth, final grade on which to lay the sod. Surface should be loose, and free of plants, trash and other debris.
- Moisten the soil immediately prior to laying sod during high temperatures to cool the soil and reduce burning and dieback.

Table 6.13 Sod Species Adaptation to Regions of the State

Species	Kansas	Missouri
Kentucky Bluegrass	East and Central	Statewide
Turf Fescue	East and Central	Statewide
Bermuda		
common	South half, east, central	Southern half
improved	South half, east, central	Southern third
Zoysia	South half, east, central	Southern half
Buffalograss	Statewide	Statewide

Laying Sod
- For best results, place the sod as soon as possible after being cut. Ideally, sod is cut and laid the same day.
- To prevent roots from drying out, moisten the soil surface and lay sod joints tightly against each other.
- Lay the first row of sod in a straight line with subsequent rows placed parallel to and laying tightly against each other. Stagger joints to create a brick-like pattern and promote more uniform growth and strength. Ensure sod is not stretched or overlapped and that all joints are butted tight to prevent spaces which cause drying of the roots. (See Figure 6.35).

- Do not lay sod on frozen soil surfaces.
- On slopes 3:1 or steeper, or wherever erosion may be a problem, lay sod with staggered joints and secure by stapling or pegging. Install sod with the length perpendicular to the water flow (on the contour).

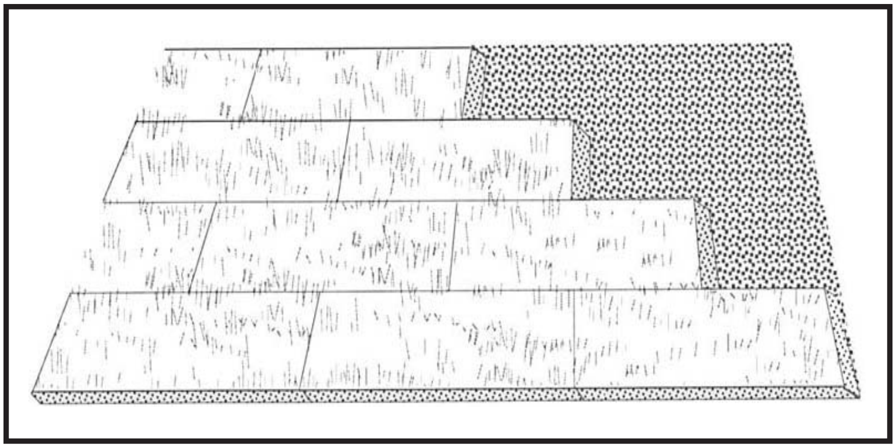


Figure 6.35 Typical installation of grass sod - lay sod in a staggered pattern with strips tightly against each other.

- Immediately after laying the sod, roll or tamp it to provide firm contact between roots and soil, then irrigate sod deeply so the underside of the sod pad and the soil 4-inches below the sod is thoroughly wet.
- Until a good root system develops, water sod as often as necessary to maintain moist soil to a depth of at least 4-inches.
- Wait until the sod is firmly rooted before mowing for the first time, usually two to three weeks. Not more than 1/3 of the grass leaf should be removed at any one cutting.

Sodded Waterways

- Sod provides quicker protection than seeding and may reduce the risk of early washout unless turf reinforcement mats are used.
- When installing sod in waterways, use the type of sod specified in the channel design.
- Lay sod strips perpendicular to the direction of water flow and stagger in a brick-like pattern. See Figure 6.36.
- Staple sod firmly at the corners and middle of each strip. Jute or synthetic netting may be pegged over the sod for further protection against washout during establishment.
- Channel velocity should not exceed 1.5 feet per second in a sodded waterway. Seek guidance from a qualified professional for additional control measures in high flow channels.

Construction Verification

Check materials and installation for compliance with specifications.

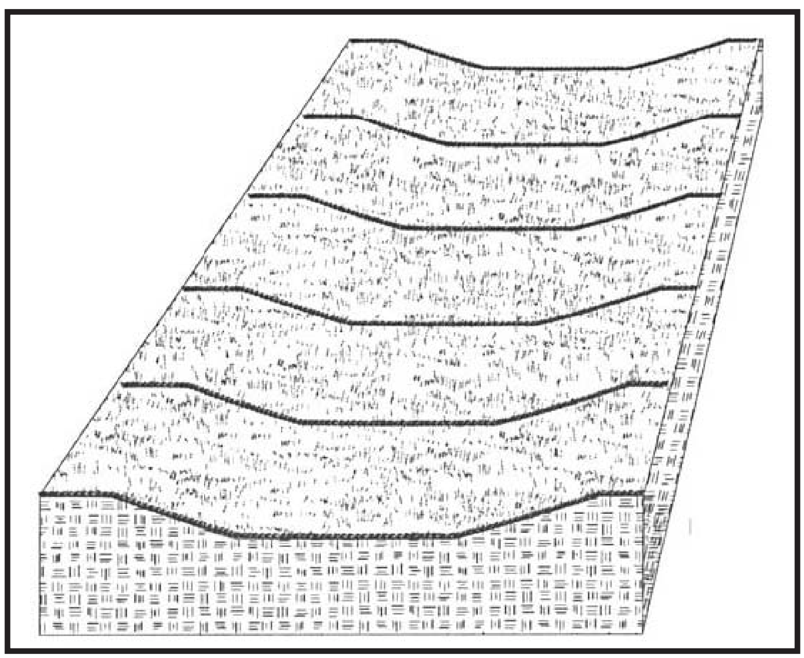


Figure 6.36 Installation of sod in waterways - lay sod across the direction of flow. Use pegs or staples to fasten sod firmly at the corners and in the center.

Maintenance and Inspection

- Inspect the sod each week and after rain events.
- Keep sod moist until it is fully rooted. Lay the sod in place at least two weeks prior to filing a Notice of Termination to allow time for sod to take root. If sod can be pulled up by hand, it has not rooted sufficiently and the site land disturbance permit can not be terminated.
- Mow to a height of 2- to 3- inches after sod is well-rooted, in two to three weeks. Do not remove more than 1/3 of the leaf blade in any mowing.
- Permanent, fine turf areas require yearly fertilization. Fertilize warm-season grass in late spring to early summer; cool-season grass in late winter and again in early fall.

Troubleshooting

Consult with a qualified design professional if any of the following occur:

- Variations in topography on-site indicate the sodding materials will not function as intended; changes in the plan may be needed.
- Design specifications for sod variety cannot be met or irrigation is not possible; substitution or seeding may be required. Unapproved substitutions could result in erosion or the sods inability to establish a root system.

Common Problems and Solutions

Problem	Solution
Grass dies because it is unable to root caused by the sod being laid on poorly prepared soil or unsuitable surface.	Remove dead sod, prepare surface and resod.
Root dieback or grass does not root rapidly and is subject to drying out caused by sod not adequately irrigated after installation.	Irrigate sod and underlying soil to a depth of 4-inches and keep moist until roots are established.
Sod may be loosened by runoff during a rain event caused by not being properly anchored.	Replace damaged areas and anchor sod.
Yellowing of leaf blades and slow growth caused by a lack of nitrogen.	Fertilize sod, but avoid fertilizing cool season grasses from late May through August.
Sod picked up and removed from soil surface caused by the hydraulic limitations of sod that may have been exceeded in the waterway.	Evaluate actual hydraulic conditions and use alterative erosion control practice, (e.g., rip rap, turf reinforcement mat, transition mats).

Soil Bioengineering for Slope Protection

Figure 6.37 Willows and other live stakes will root and sprout rapidly to protect slopes. The roots form an interlocking mat to hold soil in place, while the foliage protects the soil surface. These willows, planted along Hinkson Creek in Columbia, were 3- to 5-feet tall within six months. Source: Doug Wallace. NRCS. Boone Co.

Practice Description

Soil bioengineering consists of the use of live woody and mixed plant material to provide erosion control, slope and streambank stabilization, landscape restoration and wildlife habitat. These techniques are used alone or in conjunction with conventional engineering techniques. Soil bioengineering has the benefits of establishing permanent vegetation for decreased erosion, reduced off-site sedimentation lower runoff velocity and increased infiltration. Also, as the vegetation grows, the roots mechanically reinforce the soil and provide greater protection than just grass or a mechanical practice alone.

There are two approaches that can be used:

- Woody vegetation systems.
- Woody vegetation systems combined with reinforcing structures.

The structural part of the system helps establish vegetation on steep slopes or in areas subject to extreme erosion. Both systems provide immediate protection and grow stronger with time as the vegetation becomes established.

Soil bioengineering is advantageous where there is minimal access for equipment and workers, and in environmentally sensitive areas where minimal site disturbance is required. It is particularly suited for small, highly sensitive or steep sites. Most techniques can also be used for stream channel or bank protection. Once established, woody vegetation becomes self-repairing and needs little maintenance.

One of the best resources for soil bioengineering and slope protection is the U.S. Department of Agriculture's Natural Resources Conservation Service *Part 650: Engineering Field Handbook*. The handbook is broken into and published as many individual chapters. Chapter 16 is titled *Streambank and Shoreline Protection* and was published December 1996. Chapter 18 is titled *Soil Bioengineering for Upland Slope Protection and Erosion Reduction* and was published October 1992 with a reprinting December 1995. The *Engineering Handbook* provides standards and specifications, drawings and details of the different practices mentioned in this section. More information about bioengineering practices is available from your local National Resources Conservation Service/Soil and Water Conservation District and the Missouri Department of Conservation.

Recommended Minimum Requirements

Prior to start of construction, bioengineering practices should be designed by a registered design professional or an interdisciplinary team with knowledge of mechanical, biological and ecological concepts. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Plant Species

Native species that root easily, such as willow. Use plants suitable for the intended use and adaptation to site conditions. While willow is one of the most common groups of plants used in bioengineering, there are several other native plants that offer function and aesthetics. Plants are usually harvested from a nearby local area. Contact your local conservation office for more information.

Cutting Size

Normally ½- to 2-inches in diameter and from 2- to 6-feet long (length will depend on project requirements).

Harvesting

Cut plant materials at a blunt angle, 8- to 10- inches from the ground, leaving enough trunk so that cut plants will regrow.

Transportation and Handling

Bundle cuttings together on harvest site, removing side branches. Keep material moist. Handle carefully during loading and unloading to prevent damage. Cover to protect cuttings from drying out.

Installation Timing

Deliver to construction site within 8 hours of harvest and install immediately, especially when temperatures are above 50° F. Store up to two days if cuttings are "heeled in" moist soil, shaded and protected from wind.

Season

Install during plants' dormant season, generally late October to March.

Soil

Must be able to support plant growth with good topsoil (see Topsoiling and Stockpiling). Compact to fill voids and maintain good branch cutting-to-soil contact.

Velocities

Up to 6 feet per second for woody vegetation alone. Include simple structures with woody vegetation for velocities more than 6 feet per second. Use the velocity associated with the peak discharge of the design storm (see Streambank Protection section for structural protection alternatives).

Erosion Control
Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete. Seed and mulch bare areas on 3:1 or flatter slopes. Use netting, tackifiers or blankets with seeding on slopes steeper than 3:1.

Construction
Site Preparation
- Observe applicable government regulations especially the U.S. Army Corps of Engineers permits for work in and around waterways.
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Locate source of live rooted plants or cuttings as specified in design plan. Local sources of native plants are ideal to use. Purchase of materials from commercial sources may be necessary to comply with local regulations. Specifically, if a bioengineering project is taking place within the riparian corridor, requirements may be required under a Section 404 permit administered by the Army Corps of Engineers. In addition, local governments may also have a stream buffer ordinance requirement.
- Prepare the site by clearing, grading and shaping according to the design plan. Stockpile topsoil to be used as backfill. Stabilize the soil and slope base before any structural or streambank work is done.

Installation
- If required by the design, prepare trenches or benches in cut and fill slopes and construct structural components such as cribwalls, walls or riprap according to the plan (See Structural Protection in this section).
- Install live cuttings, checking angle of placement. Secure cuttings with stakes or as specified in plan. Schedule the work so that plants are in a dormant state to enhance the success of establishment.
- Fertilize and lime according to soil test results as specified in the design plan.
- Install filter fabric if specified in the design plan. Backfill over the vegetative cuttings, compacting the soil to achieve good live branch cutting-to-soil contact. Fill any voids around the plant materials.
- Check to see adequate soil moisture is present to encourage rooting and growth. Water, if necessary.

Woody Vegetative Protection Installation
Live staking, live fascines, brushlayers, branchpacking and live gully repair are soil bioengineering practices that use the stems or branches of living plants as a soil reinforcing and stabilizing material. Eventually the vegetation becomes a major structural component of the bioengineered system.

Live Stake
Live staking is the use of live, rootable vegetative cuttings, inserted and tamped into the ground. As the stakes grow, they create a living root mat that stabilizes the soil. Use live stakes to peg down surface erosion control materials. Most native willow species root rapidly and can be used to repair small earth slips and slumps in wet areas.

Installation

- To prepare live material, cleanly remove side branches, leaving the bark intact. Use cuttings ½- to 1½-inches in diameter and 2- to 3-feet long. Cut bottom ends at an angle to insert into soil. Cut the top of the stake square.
- Tamp the live stake into the ground at right angles to the slope, starting at any point on the slope face. Buds should point up. Install stakes 2- to 3-feet apart using triangular spacing with from two to four stakes per square yard.
- Use an iron bar to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammer head filled with shot or sand).
- Four-fifths of the live stake should be underground with soil packed firmly around it after installation. Replace stakes that split during installation.

Live Fascine

Live fascines are long bundles of branch cuttings bound together into sausage-like structures. Place them in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This practice is suited to steep, rocky slopes, where digging is difficult.

Installation

- To prepare live materials, make cuttings from species such as young willows or shrub dogwoods that root easily and have long, straight branches.
- Make stakes 2½ feet long for cut slopes and 3 feet long for fill slopes.
- Make bundles of varying lengths from 5- to 30-feet or longer, depending on site conditions and limitations in handling. Use untreated twine for bundling.
- Completed bundles should be 6- to 8-inches in diameter. Place growing tips in the same direction. Stagger cuttings so root ends are evenly distributed throughout the length of the bundle.
- Install live fascine bundles the same day they are prepared.
- Prepare dead stakes such as 2½-foot long, untreated 2- by 4-inch lumber, cut diagonally lengthwise to make two stakes. Live stakes will also work.
- Beginning at the base of the slope, dig a trench on the contour large enough to contain the live fascine. Vary width of trench from 12- to 18-inches, depending on angle of the slope.
- Trench depth will be 6- to 8-inches, depending on size of the bundle.
- Place the live fascine into the trench.
- Drive the dead stakes directly through the bundle every 2- to 3-feet. Use extra stakes at connections or bundle overlap. Leave the top of the stakes flush with the bundle.
- Install live stakes on the down slope side of the bundle between the dead stakes.

Brushlayer

Brushlayering is similar to live fascine systems. Both involve placing live branch cuttings on slopes. However, in brushlayering, the cuttings are placed at right angles to the slope contour. Use on slopes up to 2:1 in steepness and not over 15 feet in vertical height.

Installation

- Starting at the toe of the slope, excavate benches horizontally, on the contour, or angled slightly down the slope to aid drainage. Construct benches 2- to 3-feet wide. Slope each bench so that the outside edge is higher than the inside.
- Crisscross or overlap live branch cuttings on each bench. Place growing tips toward the outside of the bench.
- Place backfill on top of the root ends and compact to eliminate air spaces. Growing tips should extend slightly beyond the fill to filter sediment. Soil for backfill can be obtained from excavating the bench above.
- Space brushlayer rows 3- to 5-feet apart, depending upon the slope angle and stability.

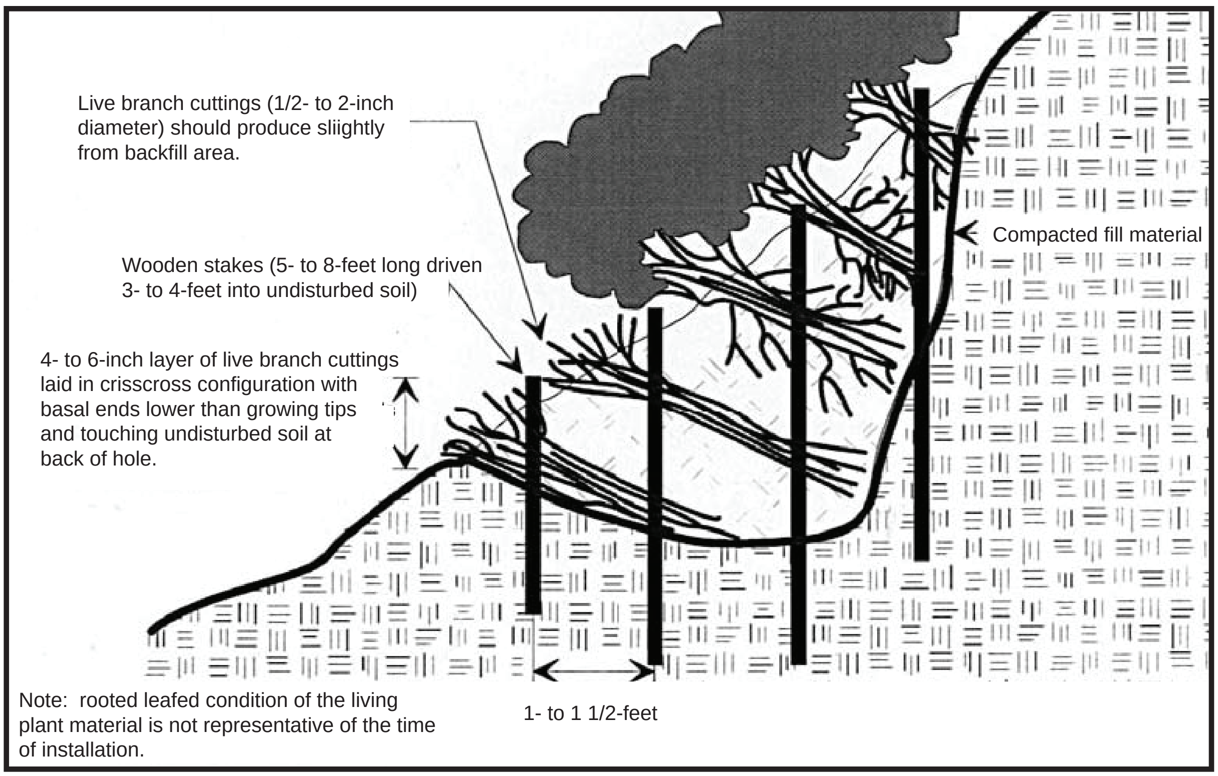


Figure 6.38 Typical branchpacking cross section. Source: *NRCS Engineering Field Handbook*, 1992.

Branchpacking

Branchpacking (see figure 6.38) consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes (no greater than 4 feet deep or 5 feet wide). Use for earth reinforcement and mass stability of small earthen fill sites.

Installation

- Make live branch cuttings from ½- to 2-inches in diameter and long enough to reach from soil at the back of the trench to extend slightly from the front of the rebuilt slope face.
- Make wooden stakes 5- to 8-feet long from 2 by 4 inch lumber or 3- to 4-inch diameter poles.
- Start at the lowest point and drive wooden stakes vertically 3- to 4-feet into the ground. Set them 1- to 1½-feet apart.

- Place a layer of living branches 4- to 6-inches thick in the bottom of the hole, between the vertical stakes, and at right angles to the slope face. Place live branches in a crisscross arrangement with the growing tips oriented toward the slope face. Some of the root ends of the branches should touch the back of the hole.
- Follow each layer of branches with a layer of compacted soil to ensure soil contact with the branch cuttings.
- The final installation should match the existing slope. Branches should protrude only slightly from the rebuilt slope face.
- Ensure that the soil is moist or moistened to ensure live branches do not dry out.

Live Gully Repair

Live gully repair uses alternating layers of live branch cuttings and compacted soil to repair small rills and gullies. This practice is limited to rills or gullies less than 2 feet wide, 1 foot deep and 15 feet long.

Installation

- Make live branch cuttings ½- to 2-inches in diameter and long enough to reach from the soil at the back of the gully and extend slightly from the front of the rebuilt slope face.
- Starting at the lowest point of the slope, place a 3- to 4-inch layer of branches at the lowest end of the rill or gully and at right angles to the slope. Cover with a 6- to 8-inch layer of fill soil.
- Install the live branches in a crisscross fashion. Place the growing tips toward the slope face with root ends lower than the growing tips.
- Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings and root ends.

Structural Protection Installation

Live cribwalls, vegetated rock gabions, vegetated rock walls and joint plantings are soil bioengineering practices that combine a porous structure with vegetative cuttings. The structures provide immediate erosion, sliding and washout protection. As the vegetation becomes established, the structural elements become less important.

Live Cribwall

A live cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber. Use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness or where space is limited and a more vertical structure is required. It should be tilted back if the system is built on a smooth, evenly sloped surface.

Installation

- Make live branch cuttings ½- to 2-inches in diameter and long enough to reach the back of the wooden crib structure.
- Build constructed crib of logs or timbers from 4- to 6-inches in diameter or width. The length will vary with the size of the crib structure.
- Starting at the lowest point of the slope, excavate loose material 2- to 3-feet below the ground elevation until a stable foundation is reached.
- Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability.
- Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4- to 5-feet apart and parallel to the slope contour. Place the next set of logs or timbers at right angles to the slope on top of the previous set.

- Place each set of timbers in the same manner and nail to the preceding set.
- Place live branch cuttings on each set to the top of the cribwall structure with growing tips oriented toward the slope face.
- Backfill crib, compacting soil for good root-to-soil contact, seed and mulch.

Vegetated Rock Gabions

Vegetated gabions combine layers of live branches and gabions (rectangular wire baskets filled with rock). This practice is appropriate at the base of a slope where a low wall is required to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large, lateral earth stresses. Use where space is limited and a more vertical structure is required. Overall height, including the footing, should be less than 5 feet.

Installation

- Make live branch cuttings from ½- to 1-inch in diameter and long enough to reach beyond the rock basket structure into the backfill.
- Starting at the lowest point of the slope, excavate loose material 2- to 3-feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability and ensure rooting.
- Place the gabions in the bottom of the excavation and fill with rock. Backfill between and behind the gabions.
- Place live branch cuttings on the gabions at right angles to the slope with the growing tips placed away from the slope and extending slightly beyond the gabions. Root ends must extend beyond the backs of the gabions into the fill material. Put soil over the cuttings and compact it.
- Repeat the construction sequence until the structure reaches the required height.

Vegetated Rock Wall

A vegetated rock wall is a combination of rock and live branch cuttings used to stabilize and protect the toe of steep slopes. This system is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness. It is useful where space is limited and natural rock is available. Height of the rock wall, including the footing, should be less than 5 feet.

Installation

- Make live branch cuttings from ½- to 1-inch in diameter and long enough to reach the soil behind the rock structure.
- Rock should range from 8- to 24-inches in diameter. Use larger boulders for the base.
- Starting at the lowest point of the slope, remove loose soil until a stable base is reached, usually 2- to 3-feet below ground elevation. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability.
- Seat rocks firmly on the foundation material. Place rocks so that their center of gravity is as low as possible, with their long axis slanting inward toward the slope, if possible. Also attempt to imbricate the rock as much as possible for streambank application.
- Provide for drainage when a rock wall is constructed adjacent to an impervious surface or in locations subject to deep frost penetration.
- A sloping bench behind the wall can provide a base on which to place live branch cuttings during construction. Tamp or place live branch cuttings into the openings of the rock wall during construction. The root ends should extend into the soil behind the wall. Place cuttings at right angles to the slope contour with growing tips protruding from the wall face.

Joint Planting

Joint planting (see Figure 6.39) or vegetated riprap involves tamping live cuttings into soil between the joints or open spaces in rocks previously placed on a slope. Use this technique where rock riprap is required. Joint planting is used to remove soil moisture, to prevent soil from washing out below the rock and to increase slope stability over riprap alone.

Installation

- Make live branch cuttings from ½- to 1½-inches in diameter and long enough to extend into soil below the rock surface. Remove side branches from cuttings leaving the bark intact.
- Tamp live branch cuttings into the openings of the rock during construction. The root ends should extend into the soil behind the riprap. Mechanical probes may be needed to create pilot holes for the live cuttings.
- Place cuttings at right angles to the slope with growing tips protruding from the finished face of the rock.

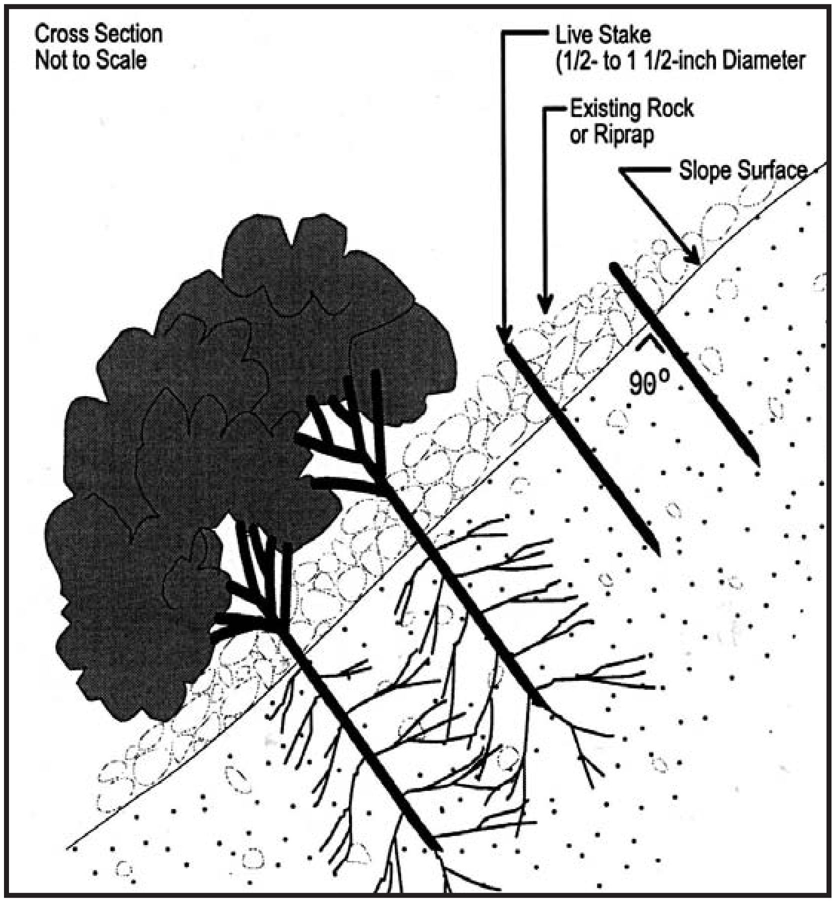


Figure 6.39 Typical Joint Planting Cross Section Source: *NRCS Engineering Field Handbook*, 1992.

Note: A detailed description, applications, effectiveness and construction guidelines for all types of bioengineering practices are discussed in Chapter 18, *Soil Bioengineering for Upland Slope Protection and Erosion Protection*, in the USDA NRCS *Part 650: Engineering Field Handbook*.

Erosion Control

Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete. Seed and mulch bare areas on 3:1 or flatter slopes. Use netting, tackifiers or blankets with seeding on slopes steeper than 3:1 (see Temporary or Permanent Seeding, Mulching and Erosion Control Blankets).

Construction Verification

For woody vegetative protection alone, check that live stakes were installed according to the design specifications. For structural protection, check that cross section of the improvements, thickness of protection and live stake installation meet with the design specifications.

Maintenance and Inspection

- For the first two months, check the treated area weekly for insects, soil moisture and other conditions that could cause failure. Water or treat with insecticide, if needed. Follow applicable federal, state and local guidelines for using insecticides next to a waterbody.
- From four to six months, check monthly and note areas where the vegetation is not growing acceptably.
- Every six months for the first two years, replace dead plants with the same species and sizes as originally specified. Install during the dormant season.
- Check the treated area after heavy rains or during drought. Fix gaps in the vegetative cover with structural materials or new plants. Make needed repairs to structural systems with similar material.
- Protect new plantings from grazing livestock or wildlife, if needed.
- After two year establishment period, maintenance requirements should be minimal. Heavy pruning may be required to reduce competition for light or stimulate new growth. Remove undesirable vegetation every 3 to 7 years.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate protection will not function as intended.	Changes in plan may be needed.
Design specifications for vegetative or structural protection cannot be met.	Substitution may be required. Unapproved substitutions could result in erosion damage to the disturbed area.
There is any indication of undermining of structural elements at their sides or base.	Consult with registered design professional.
Pressure behind the structure due to slope instability is causing any deformation to the structural elements.	Consult with registered design professional.
Erosion of treated areas; caused by inadequate vegetation or improper structural protection.	Repair erosion, replace vegetation or structural protection and consider methods to reduce or divert surface runoff from the slope, including but not limited to slope drains.
Slumping failure or slides in slope; caused by steep slopes.	Repair slide by excavating failed material, replacing vegetation and properly compacting fill. Consider flattening slope.
Sinkholes in riprap; caused by failure of the filter beneath the riprap.	Remove riprap, repair filter and reinstall riprap.
Death of vegetation; caused by drought, insect damage, cuttings damaged during installation, or poor cutting/soil contact.	Repair and replace vegetation during dormant season, maintain biweekly or monthly inspection schedule and water or treat with insecticide as needed. Follow applicable federal, state and local guidelines for using insecticides next to a waterbody.

SECTION 4: SEDIMENT CONTROLS

Fabric Drop Inlet Protection

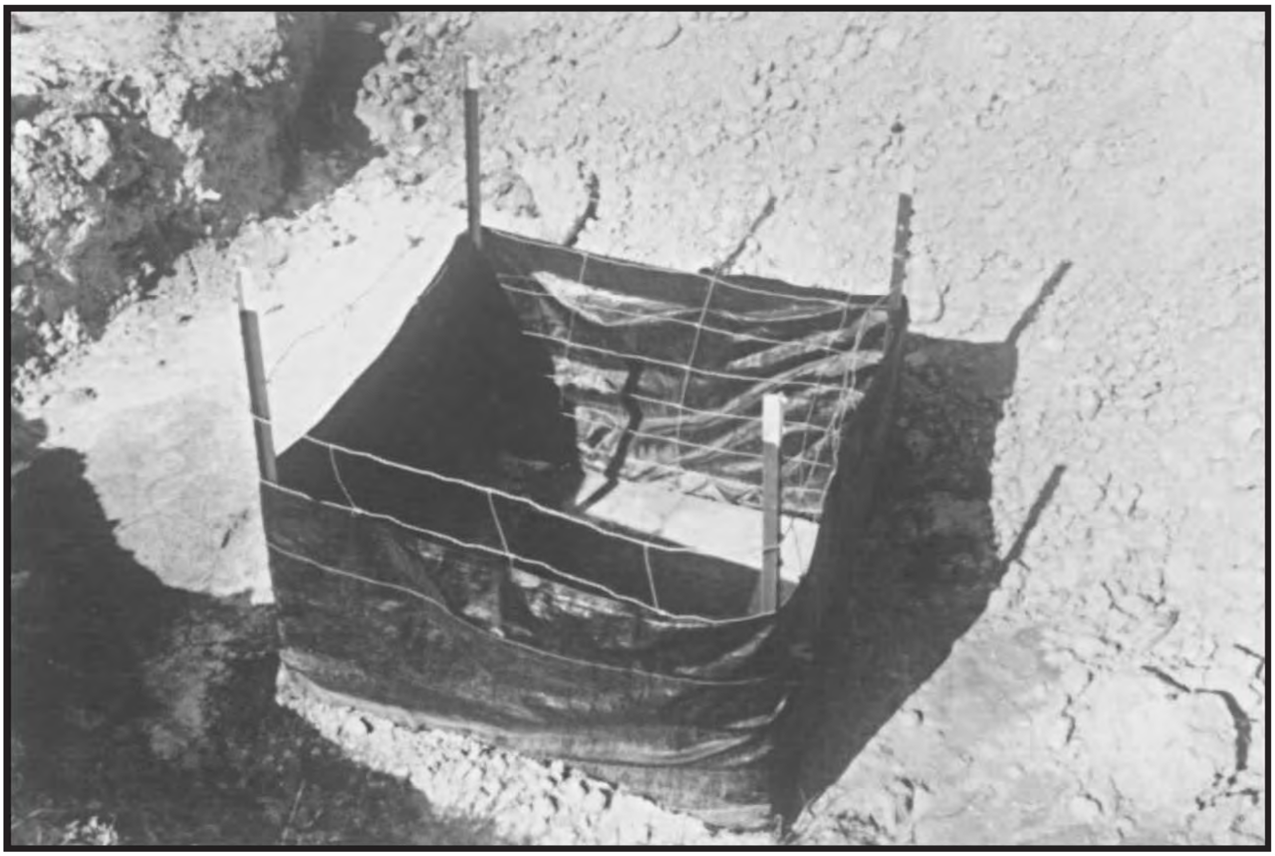


Figure 6.40 Filter fabric is only one way of protecting storm water inlets from siltation early in the grading process.

Practice Description

A fabric drop inlet protection is a temporary woven geotextile barrier placed around a drop inlet to reduce the amount of sediment entering the storm drains during construction operations. This practice applies where early use of the storm drain system is necessary.

Recommended Minimum Requirements

Prior to start of construction, fabric drop inlet protection structures should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Drainage area

Less than 1 acre per inlet.

Capacity

Ten year or design storm should enter inlet without bypass flow.

Height of Fabric

One and one-half feet maximum, 1-foot minimum; base of fabric should be buried at least 6-inches below the ground surface.

Approach

Less than 1 percent slope.

Sediment Storage

Generally 35 yard^3/disturbed acre/year for watershed slopes of under 8 percent; 100 yard^3/disturbed acre/year for slopes more than 8 percent.

Support Posts

Steel fence posts or 2 x 4 inch wooden posts. Minimum length of the stakes should be 3-feet; maximum spacing of stakes should be 3-feet.

Fabric

Durable, high-strength synthetic woven fabric.

Framing

Use frame cross members to connect the tops of the posts to stabilize the structure.

Stakes

Close to the drop inlet so overflow will fall directly into the structure and not onto unprotected soil.

Approach

Less than 1 percent slope.

Sediment Storage

Generally 35 yard^3/disturbed acre/year for watershed slopes of under 8 percent; 100 yard^3/disturbed acre/year for slopes more than 8 percent.

Support Posts

Steel fence posts or 2 x 4 inch wooden posts. Minimum length of the stakes should be 3-feet; maximum spacing of stakes should be 3-feet.

Fabric

Durable, high-strength synthetic woven fabric.

Framing

Use frame to connect the tops of the posts to stabilize the structure.

Stakes

Close to the drop inlet so overflow will fall directly into the structure and not onto unprotected soil.

Safety

Provide protection to prevent children from entering the inlet and outlet.

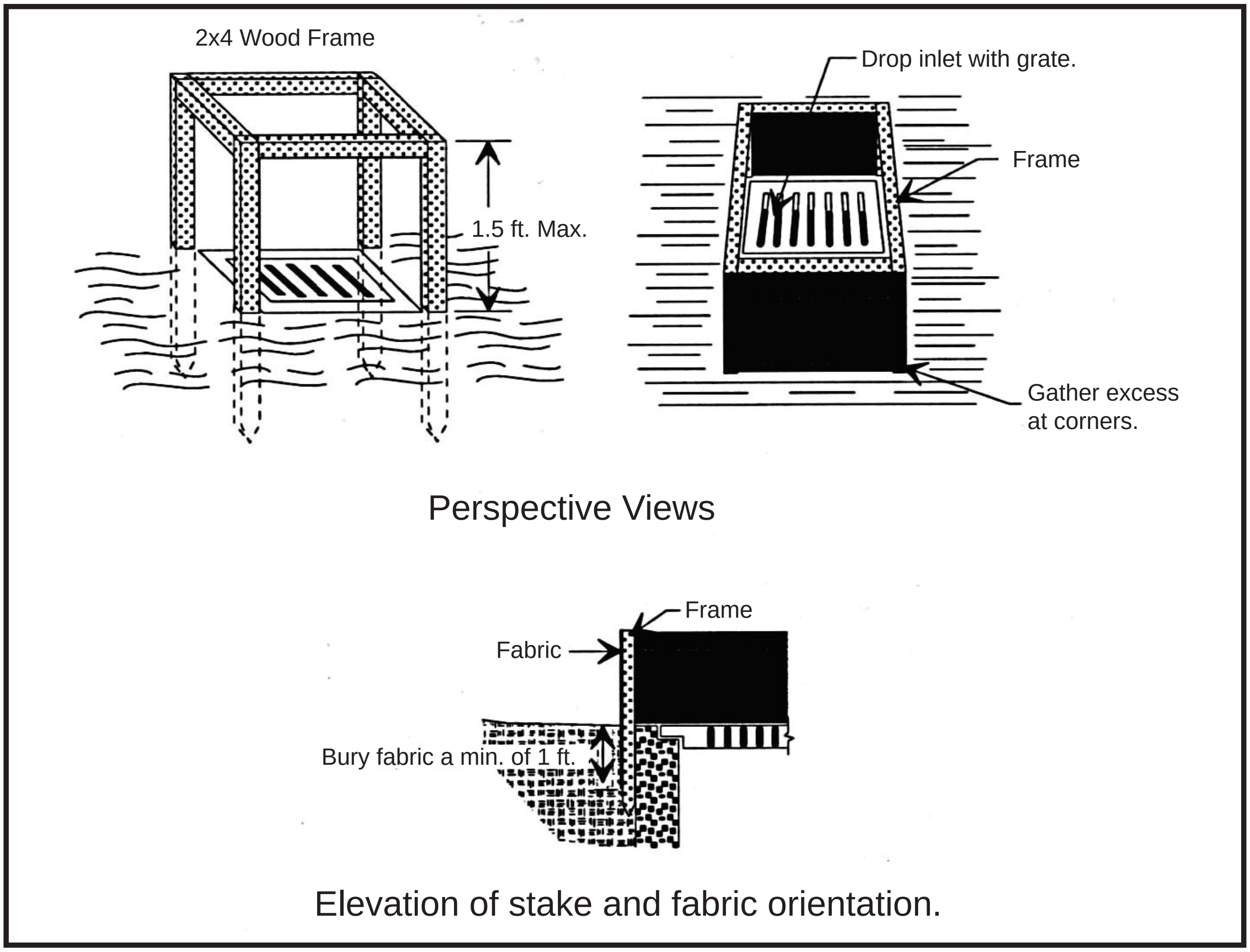


Figure 6.41 Fabric Drop Inlet Protection

Construction

- Space stakes evenly around the perimeter of the inlet a maximum of 3-feet apart and securely drive them into the ground, approximately 18-inches deep.
- To provide needed stability to the installation, frame with 2 x 4 inch wood strips or other suitable materials around the crest of the overflow area at a maximum of 18-inches above the drop inlet crest.
- If possible, cut fabric from one continuous roll to eliminate joints.
- Place the bottom 12-inches of the fabric in a trench and backfill the trench with crushed stone or compacted soil.
- Fasten the fabric securely to the stakes and frame. Joints should be overlapped to the next stake.
- Optional: Wire fence may be used to support the fabric. The wire should be 14-gage minimum with maximum mesh spacing of 6-inches. The top of the fence should be level, and the bottom should be buried at least 6-inches below ground surface.
- The top of the frame and fabric must be well below the ground elevation downslope from the drop inlet to keep runoff from bypassing the inlet. It may be necessary to build a temporary dike on the downslope side of the structure to prevent bypass flow. Material from within the sediment pool may be used for dike construction.

Stabilization
Stabilize all bare areas around the inlet.

Construction Verification
Check finished grades and dimensions of fabric drop inlet protection structures.
Verify sturdiness of frame construction.

Troubleshooting
Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate fabric drop inlet protection will not function as intended; changes in plan may be needed.
- Design specifications for posts, fabric or fencing cannot be met; substitution may be required. Unapproved substitutions could result in failure of the structure.
- Fabric clogs or creates flooding due to ponding of storm water flows.

Maintenance, Inspection and Removal
- Inspect fabric barrier and frame weekly and after each rainfall event and make needed repairs immediately.
- Remove sediment from the pool area as necessary to restore required storage volume for the next rain. Take care not to damage or undercut the fabric during the sediment removal.
- When the contributing drainage area has been adequately stabilized, remove all materials and unstable sediment and dispose of properly in an upland area to dry and be stabilized. Bring the disturbed area to the grade of the drop inlet; smooth and compact it.
- Remove the temporary fabric drop inlet protection stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Overtopping of fence; caused by posts and fabric unsupported at top.	Repair frame as necessary and use frame to support tops of post and fence to support fabric.
Undercutting of fence; caused by fabric not properly buried at bottom.	Use proper installation to bury fabric (see Figure 5.44)
Inadequate storage volume for the next storm; caused by sediment not being removed from pool.	Remove sediment as needed to prevent build-up.
Flow bypassing the inlet; caused by top of fabric set too high.	Lower top of fabric or select other inlet protection device.
Erosion and undercutting of inlet; caused by fence not close enough to inlet.	Relocate fence adjacent to inlet.
High flow velocity and poor trapping efficiency; caused by steep slopes at drain inlet.	Flatten slope at inlet.
Flooding; high water ponding around inlet; caused by improper selection of best management practice.	Reevaluate appropriate best management practice inlet protection device.

Excavated Drop Inlet Protection

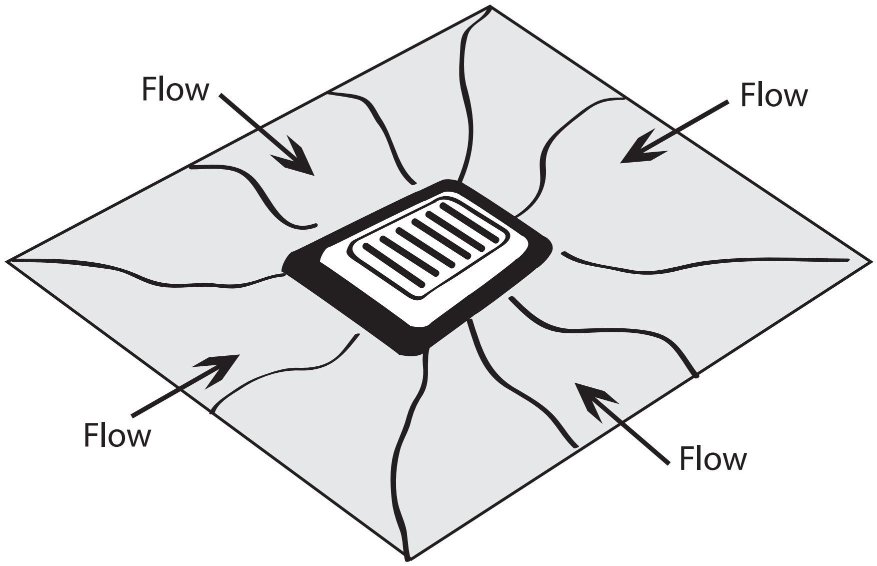


Figure 6.42 Perspective of Excavated Drop Inlet Protection

Practice Description

An excavated area in the approach to a storm drain drop inlet or curb inlet. The purpose is to trap sediment at the approach to the storm drainage system and not permit sediment to flow into the storm drain. This practice applies where early use of the storm drain system is necessary.

Recommended Minimum Requirements

Prior to start of construction, excavated drop inlet protection structures should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Drainage Area

Less than 1 acre per inlet.

Capacity

Ten year or design storm should enter inlet without bypass flow.

Minimum Depth

One foot, as measured from the top of the drop inlet.

Maximum Depth

Two feet, as measured from the top of the drop inlet.

Side Slopes

Side slopes at 2:1 or flatter around the excavation.

Dewatering

Place drain holes in drop inlet, covered with wire screen and gravel.

Gravel

Use clean gravel, 1/2- to 3/4-inches in diameter.

Sediment Storage
Keep the minimum volume of excavated material around the drop inlet at approximately 35 yd^3/ disturbed acre.

Basin Shape
To fit site conditions, with the longest dimension placed toward the longest inflow area to provide maximum settling efficiency. Try to keep the slopes less than 2:1 and allow access for excavation equipment for sediment removal, if possible.

Drain
Install provision for draining the temporary pool to improve trapping efficiency for small storms and to avoid problems from standing water after heavy rains.

Safety
Provide protection to prevent children from entering the inlet or outlet.

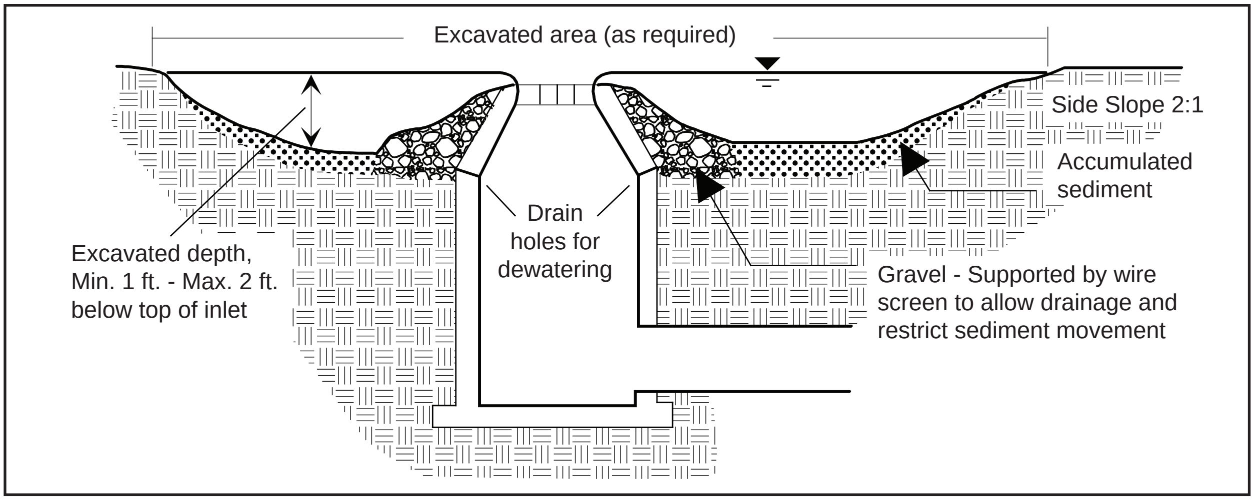


Figure 6.43 Cross section of Excavated Drop Inlet Protection

Construction
Site Preparation
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Clear the area of all debris that might hinder excavation and disposal of spoil.
- Excavate the basin to the depth, side slopes and dimensions shown on the plans.
- Grade the approach to the inlet uniformly.
- Install drain holes in the drop inlet to drain pool slowly. Cover holes with wire screen and place gravel around sides of inlet.
- When necessary, spoil may be placed to form a dike on the downstream side of the excavation to prevent bypass flow.

Erosion Control
Stabilize disturbed areas, except the excavated pool bottom, in accordance with vegetation plan.

Construction Verification
Check finished grades and dimensions of excavated drop inlet protection structures.

Troubleshooting

Consult with a registered design professional if the following occurs:

- Variations in topography on-site indicate excavated drop inlet protection will not function as intended; changes in plan may be needed.

Maintenance, Inspection and Removal

- Inspect, clean and properly maintain the excavated basin after every storm as needed until the contributing drainage area has been permanently stabilized. While removing sediment from around inlet, do not allow accumulated sediment to discharge into unprotected inlet.
- Remove sediment when the excavated volume is approximately one-half full.
- Spread all excavated material evenly over the surrounding land area or stockpile and stabilize it appropriately.
- When the contributing drainage area has been permanently stabilized, seal drain holes, fill the basin with stable soil to final grading elevations, compact it properly, and establish vegetation or provide other means of protection.
- Remove the temporary excavated drop inlet protection stabilize the site prior to filing *Form H: Request for Termination of a General Permit, Form--MO 780-1409* (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Sediment entering drain; caused by sediment producing area too large for basin design or inlet not properly maintained.	Enlarge basin and maintain inlet (remove sediment, refresh filter fabric and rock).
Excessive ponding; caused by gravel over drain holes plugged with sediment.	Remove debris, clear sediment and replace gravel.
Flooding and erosion; caused by blockage of the storm drain from debris entering inlet.	Install trash rack around inlet.

Block and Gravel Inlet Protection

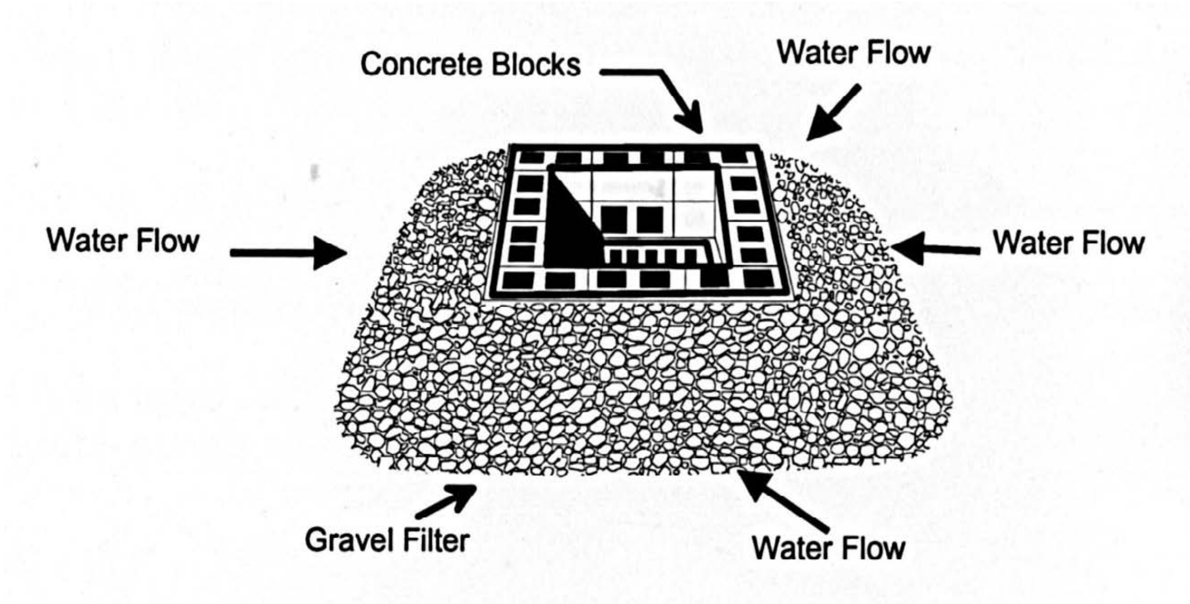


Figure 6.44 Detail of block and gravel drop inlet

Practice Description

Block and gravel inlet protection is a sediment control barrier formed around a storm drain inlet by the use of standard concrete block and gravel. The purpose is to help prevent sediment from entering storm drains before the disturbed construction area is revegetated and stabilized. This practice applies where early use of the storm drain system is necessary.

Recommended Minimum Requirements

Prior to start of construction, block and gravel inlet protection structures should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Drainage Area

Less than 1 acre.

Capacity

Ten year or design storm should enter inlet without bypass flow.

Height

Height of barrier should be between 1 and 2 feet. Be aware of potential ponding issues and provide emergency overflows to prevent possible excessive flooding.

Side Slopes

Gravel placed around the concrete block structure should have side slopes of 2:1 or flatter.

Dewatering

Some blocks in bottom row should be placed on their side for drainage.

Gravel
Use clean gravel, 1/2- to 3/4-inches in diameter. Place hardware cloth or comparable wire mesh with half inch openings over all block openings to hold gravel in place.

Safety
Provide protection to prevent children from entering the pipe inlet.

The top elevation of the structure must be at least 6-inches lower than the ground elevation downslope from the inlet. It is important that all storm flows pass over the structure and into the storm drain and not past the structure. Temporary dikes below the structure may be necessary to prevent bypass flow. Material may be excavated from inside the sediment pool for this purpose.

Construction
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Clear area of all debris that might hinder excavation and disposal of spoil.
- Grade the approach to the inlet uniformly.
- Lay one block on its side in the bottom row on each side of the structure to allow pool drainage. The foundation should be excavated at least 2-inches below the crest of the storm drain. Place the bottom row of blocks against the edge of the storm drain for lateral support and to avoid washouts when overflow occurs. If needed, give lateral support to subsequent rows by placing 2 x 4 inch wood studs through block openings.
- Carefully fit hardware cloth or comparable wire mesh with half inch openings over all block openings to hold gravel.
- Place gravel around blocks on a 2:1 slope or flatter, 2-inches below the top of the blocks, and smooth to an even grade.

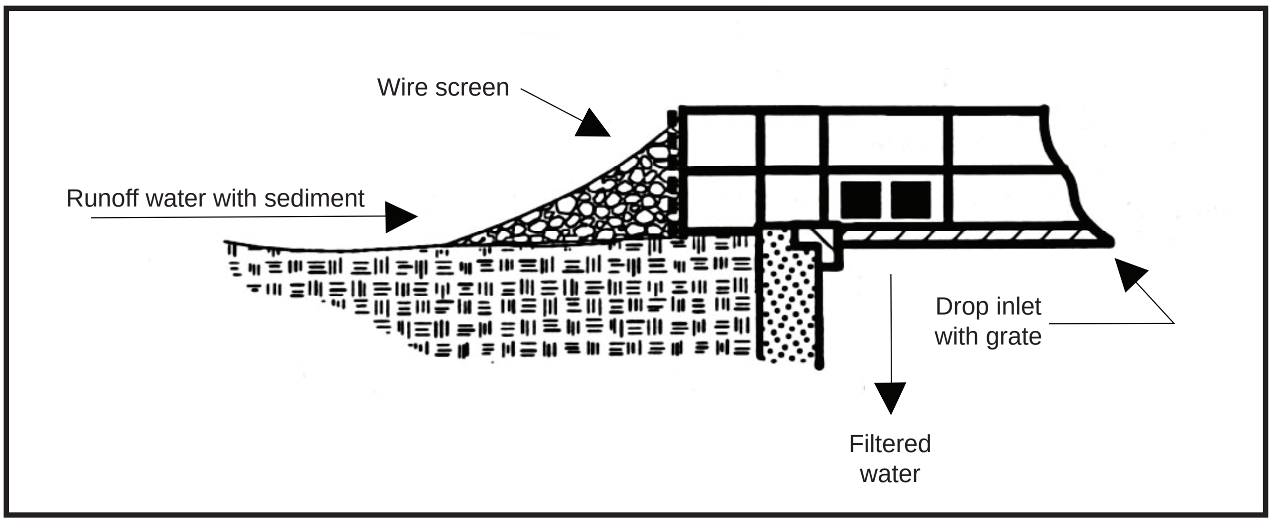


Figure 6.45 Cross section detail of block and gravel drop inlet.

Erosion Control
Stabilize disturbed areas in accordance with the vegetation plan.

Construction Verification
Check finished grades, material sizing and dimensions of block and gravel drop inlet protection structures.

Troubleshooting

Consult with registered design professional if variations in topography on-site indicate block and gravel drop inlet protection will not function as intended; changes in plan may be needed.

Maintenance, Inspection and Removal

- Inspect the barrier after each rain and make repairs as needed.
- Remove sediment as necessary to provide adequate storage volume for subsequent rains and replace gravel surrounding the inlet as it fills with sediment.
- When the contributing drainage area has been adequately stabilized, remove all materials and any unstable soil, and salvage or dispose of it properly. Bring the disturbed area to proper grade, then smooth and compact it. Appropriately stabilize all bare areas around the inlet.
- Remove the temporary block and gravel inlet protection stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Bypass flow and erosion; caused by top of structure being too high.	Lower height of structure.
Scour; caused by blocks not placed firmly against the storm drain inlet.	Reset blocks firmly against drain inlet.
Poor trap efficiency or sediment overload; caused by too large of a drainage area.	Increase size of temporary sediment pool.
Poor trap efficiency; caused high flow velocity due to too steep of an approach to the drain.	Use excavated basin (see Excavated Drop Inlet Protection).
Sediment entering the storm drain; caused by sediment not being removed promptly.	Remove sediment promptly following storms.

Domed Inlet Protection

Figure 6.46 These are the two parts to this domed inlet device. Here it is secured to the ground weighted with gravel.
Source: Silt Saver Inc.

Definition and Purpose

This domed inlet protection device has two parts. There is a reusable HDPE (high-density polyethylene) frame and a hat that fits over the frame made primarily of two fabrics, a non-woven geotextile on the lower part and an open weave geotextile on the upper part. The open weave will allow for stormwater discharging quicker and reducing depth of ponded water. The frame has super stress crack resistance combined with high impact strength and rigidity. The base can be either round or square depending on the configuration of your storm sewer inlet openings.

Recommended Minimum Requirements

These inlet protection devices should be installed immediately after the storm sewer is constructed so stub openings can be protected before the next storm event.

Construction

These devices are manufactured and purchased from area distributors. The device should be installed over the opening and small stone or sand bags placed in the pockets at the bottom of the geotextile cover to keep the cover in place over the rigid cap.

Maintenance, Inspection and Removal

- Inspect each inlet protection device weekly and after rain events. Clean any sediment accumulation and dispose of sediment in a proper manner.
- Replace the geotextile cover if it is torn or damaged.
- While inspecting and cleaning inlet, do not allow accumulated sediment to discharge into unprotected inlet.
- Removal of this temporary domed inlet protection must be performed and the site stabilized prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Any inlet protection device has the potential to create ponding. Protection devices that completely block the inlet or reduce the flow to the inlet can cause flooding or bypass of the storm flow to the next inlet down stream of the protected inlet.	Choose the inlet protection device according to the specific situation on your construction site.
Flooding during storm event; caused by the inlet device being completely blocked.	Choose the appropriate inlet protection device according to the situation on your site and provide routine and adequate maintenance.

Inlet Bag or Insert

Figure 6.47 Inlet Bag goes around grate.
Source: Dandy Products Inc.

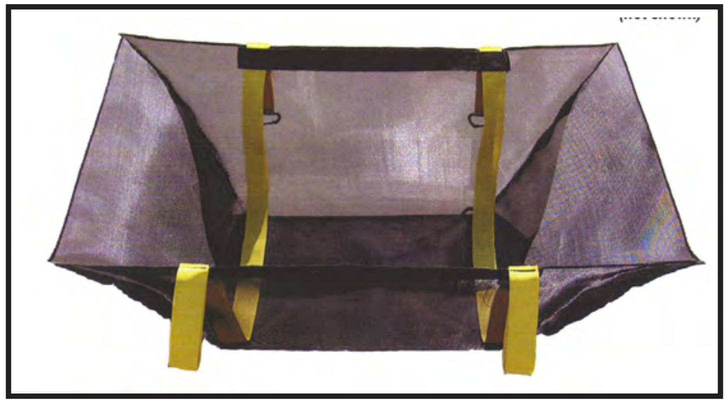


Figure 6.48 Inlet protection insert goes inside the storm drain.
Source: Pollution Solution Inc.

Practice Description

Inlet bags or inserts are inlet protection devices that are manufactured in a bag or sack form and completely cover or surround the inlet grate or fit around the grate and are suspended below the grate to collect the sediment within the storm sewer pipe. Most often the material is a geotextile but can be made of many types of materials. Some of these products are inlet bags that go around the grate or inserts that go inside the storm drain.

To provide some protection against excessive ponding, some manufacturers incorporate overflow tubes in their design that allow storm water to bypass through the bag or insert if the ponding level reaches a certain height.

Recommended Minimum Requirements

All storm sewer inlets that discharge stormwater off-site must be protected to treat the storm water discharge before it exits the construction site. Partially or completely blocking the inlet with a sediment control device will create ponding and possible bypasss or flooding. Keep this in mind when selecting which protection device you choose.

Construction

These products are manufactured and you must follow manufactures requirements for installation and maintenance.

Maintenance, Inspections and Removal

- Inspect each device weekly and after each storm event. Remove accumulated sediment around or in device and then wash device to clear it of sediment and replace it on or into the storm sewer inlet. While cleaning devise, do not allow sediment to discharge into the unprotected inlet.
- Remove the temporary inlet bag or insert and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Bypass and flooding are the two largest issues with inlet protection devices. Select the device that best fits the situation you have on your construction site knowing you may need to change devices during different stages of construction.

Common Problems and Solutions

Problem	Solution
Flooding during storm event; caused by the inlet device being completely blocked.	Choose the appropriate inlet protection device according to the situation you have on your site and provide routine and adequate maintenance.

Figure 6.49 Inlet cover with opening for overflow.

Sediment Fence

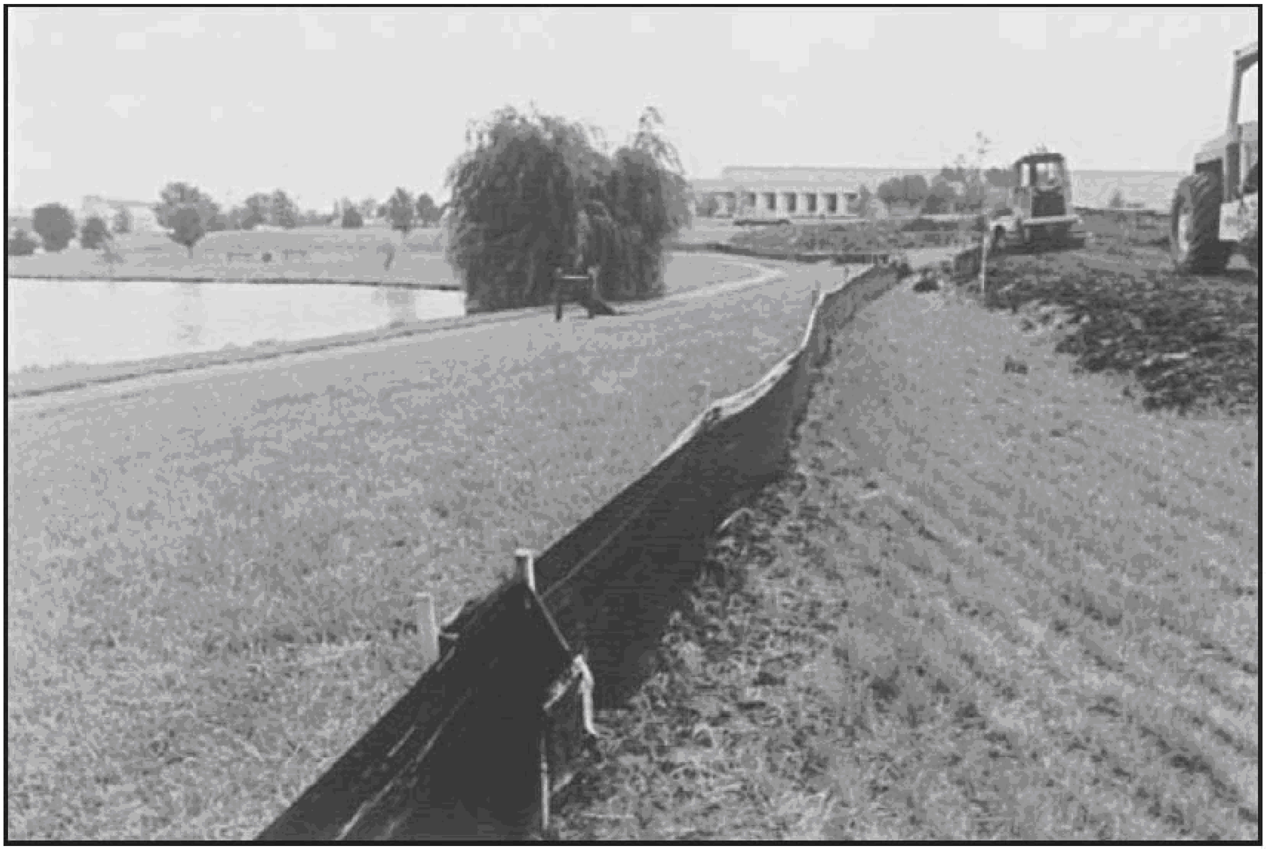


Figure 6.50 A properly installed sediment fence slows water flow long enough for the sediment to settle out. There should be no gaps under fence if heeled in properly. Source: C. Rahm, NRCS. Platte Co.

Practice Description

A sediment fence (often called a silt fence) is a temporary sediment barrier consisting of a geotextile fabric that is attached to supporting posts and trenched into the ground. Sediment-laden runoff ponds uphill from the sediment fence and runoff is temporarily stored to allow sediment to settle out of the water.

This practice applies where sheet erosion occurs on small disturbed areas. Sediment fences are intended to intercept and detain small amounts of sediment from disturbed areas in order to prevent sediment from leaving the site. Sediment fences can also prevent sheet erosion by decreasing the velocity of the runoff. Silt fence is not intended to be used in concentrated flow paths.

Recommended Minimum Requirements

Prior to start of construction, sediment fence placement and installment methods should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Drainage Area

Limit to ¼ acre per 100 feet of fence. Further restrict the area by slope steepness as shown in Table 5.16.

Location

Fence should be built on a nearly level grade and at least 10 feet from the toe of the slope to provide a broad shallow sediment pool. Install on the contour, where fence can intercept runoff as a sheet flow; not located crossing channels, waterways or other concentrated flow paths; not attached to existing trees; and not located vertically up the slope (at a right angle to the slope.)

J-Hook

Silt fence should not be used around the entire perimeter of the site unless it is a small, flat site. It should only be located at areas where stormwater flow discharges with overland or sheet flow. You can use silt fence to create small catchments of stormwater flow by creating a small J-hook shape with the silt fence. The drainage area should be less than ¼ acre with little or no slope (see Figure 3.83).

Length

Maximum of 600 feet; flare ends of fence uphill to temporarily impound water as shown in Figure 5.32.

Geotextile

Commercially available silt fence fabric is almost exclusively woven geotextile fabric. Non-woven material has better flow through but poorer strength. A higher porosity geotextile would be a mono-filament fabric with larger voids between the woven threads.

Table 6.14 Typical Land Slope and Distance for Sediment Fence

Land Slope (percent)	Maximum Slope Distance* above Fence (feet)
Less than 2	100
2 to 5	75
5 to 10 greater than 10	50*

*** Follow manufacturers' recommendations for proper spacing.**

Spacing of Support Posts

A good minimum stand is 6-feet maximum for geotextile fabric supported by wire and 5-feet maximum for geotextile fabric without supportive wire backing. Follow the local design standards in your area and the site SWPPP.

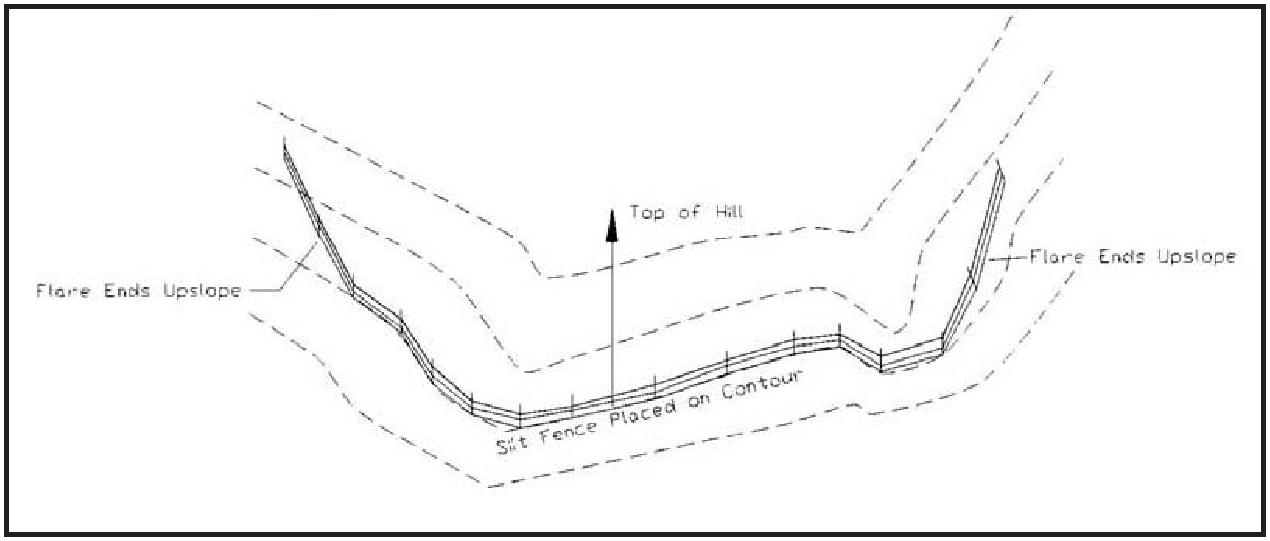


Figure 6.51 Placement of sediment fence

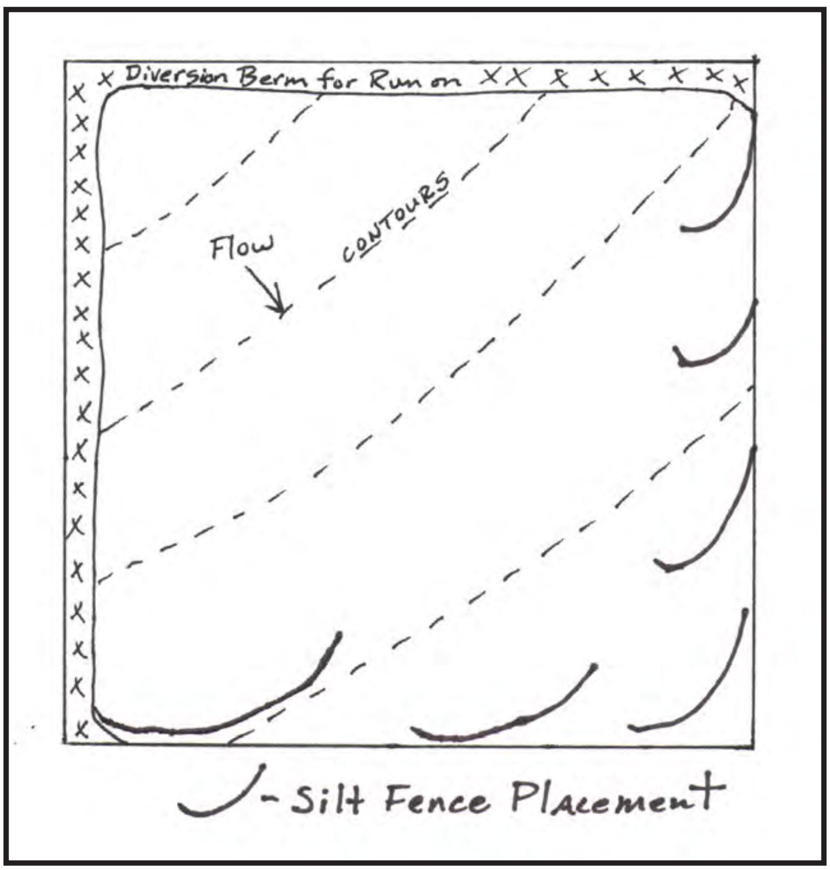


Figure 6.52 Placement of J-hook silt fence along the perimeter of a construction site to slow and pond small areas of stormwater runoff.

Proper Installation of Silt Fence

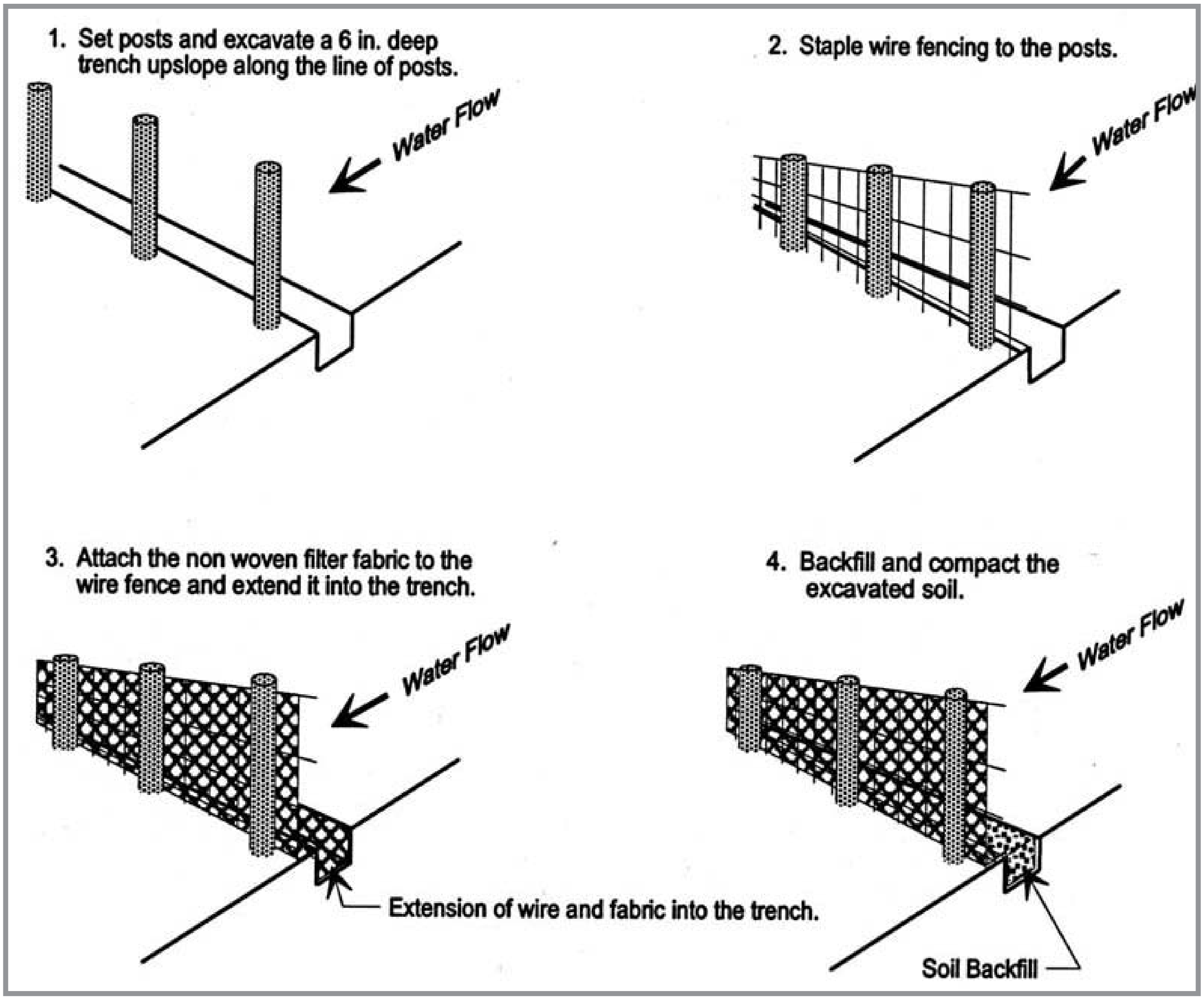


Figure 6.53 Proper Installation of silt fence

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Grade alignment of fence as needed to provide broad, nearly level area upstream of fence.

Fence Installation

- Dig a trench at least 6-inches deep along the fence alignment as shown in Figure 5.84.
- Drive hard wood or steel posts at least 24-nches into the ground on the downslope side of the trench. Space posts a maximum of 6-feet if fence is supported by wire, or 5-feet if no reinforcing wire fence is used.
- Fasten support wire fence to upslope side of posts, extending 6-inches into the trench as shown in Figure 5.84.
- Attach continuous length of fabric to upslope side of fence posts. Try to minimize the number of joints. Avoid joints at low points in the fence line. Where joints are necessary, fasten fabric securely to support posts and overlap to the next post.

- Place the bottom 1-foot of fabric in the 6-inch deep trench (minimum), lapping toward the upslope side. Backfill with compacted earth or gravel as shown in Figure 5.85.
- To reduce maintenance, excavate a shallow sediment storage area in the upslope side of the fence.
- Provide good access in areas of heavy sedimentation for clean out and maintenance.

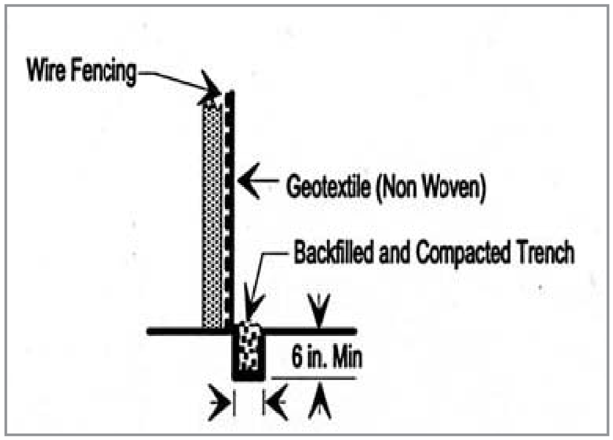


Figure 6.54 Detail of sediment fence installation

Reinforced Stabilized Outlet Installation

- Allow for safe bypass of storm flow to prevent overtopping failure of fence.
- Set outlet elevation so water depth cannot exceed 1.5 feet at the lowest point along the fence.
- Drive posts securely at least 24 inches into the ground, at a spacing of 5- to 6-feet depending on the use of wire fence reinforcement or not. Install a horizontal brace between the support posts to serve as an overflow weir and to support the top of the fabric.
- Immediately downslope of the fabric, excavate foundation for splashpad a minimum of 5-feet wide, 5-feet long and 1-foot deep. Place 1-foot of riprap in the excavated foundation. The surface of the riprap should be flush with the undisturbed ground (no outfall).

Erosion Control

Stabilize disturbed areas in accordance with landscape plan.

Construction Verification

Check finished grades and dimensions of the sediment fence. Check materials for compliance with specifications.

Maintenance, Inspection and Removal

Inspect sediment fences at least once a week and after each rainfall as dictated by your permit. Make any required repairs immediately.

- Immediately replace the fabric of the sediment fence should it collapse, tear, decompose or become ineffective.
- Remove sediment deposits as necessary to provide adequate storage volume for the next rain event and to reduce pressure on the fence. Take care to avoid damaging or undermining the fence during cleanout.
- Remove all fencing materials and unstable sediment deposits and bring the area to grade and stabilize it after the contributing drainage area has been properly stabilized.
- Remove the temporary sediment fence and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on-site indicate sediment fence will not function as intended; changes in the plan may be needed.
- Design specifications for geotextile fabric, support posts, support fence, gravel or riprap cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.
- Fence is not installed on the contour or is installed across channels or other concentrated flow areas.
- Installation of sediment fence as designed appears to create a potential flooding hazard or directs runoff overflows into sensitive ecological areas.

Common Problems and Solutions

Problem	Solution
Overtopping, sagging or collapse of fence occurs; caused by the drainage area too large or too much sediment accumulation allowed before cleanout.	Increase sediment storage capacity upslope of fence or remove accumulation more frequently, then repair fence.
Collapse of fence due to high velocity or undercutting of fence; caused by approach too steep.	Reduce slope of approach area, or consult with a registered design professional.
Sagging or collapse of fence; caused by fence not adequately supported.	Add additional supports.
Undercutting of fence; caused by the bottom of fence not buried properly.	Reinstall fence using proper method of trenching.
Sagging, collapse or undercutting of fence; fence installed across drainage way.	Relocate fence away from drainage way. Silt fence should only be used adjacent to drainageway; other devices should be used across or within drainageway (see Rock Check Dam or Ditch Check).
Water runs on both sides of fence; fence installed vertically or at right angle to contour.	Relocate fence along contours.

Fence should never be used as a check dam or in concentrated flow paths.

Temporary Diversions

Figure 6.55 An unfinished temporary diversion routes sediment-laden storm water to a sediment basin. Temporary diversions should be shaped and protected with a turf reinforcement mat or rock. Establish permanent vegetation if the diversion will be used for one year or more. Source: K. Grimes, Soil and Water Conservation District. St. Charles Co.

Practice Description

A temporary diversion is a temporary ridge or excavated channel or combination ridge and channel. It is designed to either prevent runoff from flowing across the active construction site work areas and discharge it through stable, protected outlets or to divert sediment laden water to sediment traps. Temporary diversions are usually constructed by excavating a channel and using the excavated material to construct a ridge on the down slope side of the channel.

This practice applies wherever storm water runoff must be temporarily diverted to protect disturbed areas and slopes or to retain sediment on-site during construction. When a diversion is needed to direct runoff from undisturbed areas above the construction site around a disturbed area, it must be routed to a stabilized outlet. The diversion must be fully stabilized and non-erodible prior to receivingstorm water flows. Check dams may be installed within the diversion to reduce velocities and control flows better. A diversion of cleanstorm water flow should never be allowed to flow over disturbed areas and create erosion or pick up sediment in the flow. If the untreated flow mixes with sediment ladenstorm water on the construction site, it must be treated through a control device before it discharges off-site.

Recommended Minimum Requirements

Prior to start of construction, temporary diversions should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. Temporary diversions should be constructed to minimize erosion at the design flow.

Drainage Area

Less than 5 acres.

Ridge Design

- Side Slope: 2:1 or flatter; 3:1 or flatter where vehicles must cross.
- Top Width: 2.0 ft.
- Freeboard: 0.3 ft.
- Settlement: 10 percent of fill height.

Channel Design

- Side Slope: 2:1 or flatter; 3:1 or flatter where vehicles must cross.
- Grade: Stable, positive grade towards outlet, but not exceeding 2 percent.

Construction

Site Preparation

- Locate and mark the alignment of the diversion as shown on the plans. The alignment should maintain a stable, positive grade toward the outlet. Minor adjustments to the grade and alignment may be required by site conditions. Realign or elevate the diversion as needed to avoid reverse grade.

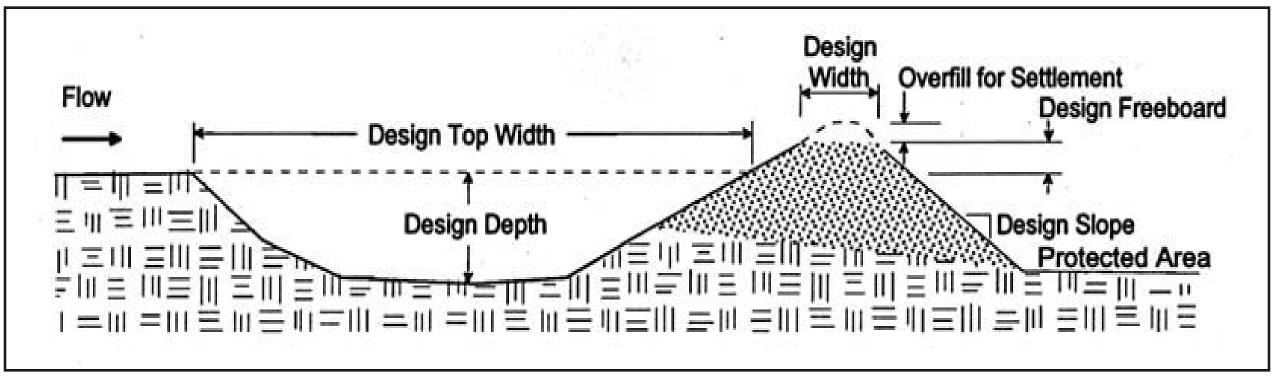


Figure 6.56 Typical temporary combination diversion.

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Remove trees, brush, stumps and other unsuitable material from the site.
- Disk the base of the ridge before placing fill.

Grading

- Construct the diversion to the dimension and grades shown on the design.
- Build the ridge 10 percent higher than designed for settlement and compact with wheels of the construction equipment or sheep foot roller.
- Leave sufficient area along the diversion to permit clean out and regrading.

Erosion Control

- Stabilize the outlets in accordance with design plans during construction of the diversion.
- Vehicles should not be allowed to drive across through diversions.
- Stabilize ridges, side slopes and channels with vegetation or synthetic erosion control measures as specified in the design. Do not allow storm water flows to enter the channel until it is fully stabilized especially if it is being used to direct clean storm water around a disturbed area.
- Outlet should be nonerosive for design flow. Divert flow containing sediment to sediment trap or basin.
- Stabilize ridge with vegetation if in place more than 30 working days.
- Diversions should not be installed on slopes greater than 15 percent or where diversion flows are calculated to be greater than 3-feet per second over vegetation. If the diversion is constructed above a steep slope, install temporary slope drains or other stable outlet to control runoff and prevent erosion of the slope (see Temporary Slope Drains, Grass-lined Channel, Riprap-lined Channel or Turf Reinforcement Mats).

Construction Verification

- The field inspector should verify the dimensions shown on the plans for the following: depth, bottom width, top width, side slopes of channel and ridge, grade of channel bottom, ridge height and channel stabilization techniques.
- Check all of the finished grades and configuration of all channels to eliminate constrictions to flow and to ensure final discharge flows to sediment basins or stabilized outlets. Also check all ridges for low spots and stability.

Grading

- Construct the diversion to the dimension and grades shown on the design.
- Build the ridge 10 percent higher than designed for settlement and compact with wheels of the construction equipment or sheep foot roller.
- Leave sufficient area along the diversion to permit clean out and regrading.

Erosion Control

- Stabilize the outlets in accordance with design plans during construction of the diversion.
- Vehicles should not be allowed to drive across through diversions.
- Stabilize ridges, side slopes and channels with vegetation or synthetic erosion control measures as specified in the design. Do not allow storm water flows to enter the channel until it is fully stabilized especially if it is being used to direct clean storm water around a disturbed area.
- Outlet should be nonerosive for design flow. Divert flow containing sediment to sediment trap or basin.
- Stabilize ridge with vegetation if in place more than 30 working days.
- Diversions should not be installed on slopes greater than 15 percent or where diversion flows are calculated to be greater than 3-feet per second over vegetation. If the diversion is constructed above a steep slope, install temporary slope drains or other stable outlet to control runoff and prevent erosion of the slope (see Temporary Slope Drains, Grass-lined Channel, Riprap-lined Channel or Turf Reinforcement Mats).

Construction Verification

- The field inspector should verify the dimensions shown on the plans for the following: depth, bottom width, top width, side slopes of channel and ridge, grade of channel bottom, ridge height and channel stabilization techniques.
- Check all of the finished grades and configuration of all channels to eliminate constrictions to flow and to ensure final discharge flows to sediment basins or stabilized outlets. Also check all ridges for low spots and stability.

Maintenance, Inspections and Removal

- Inspect weekly and following each storm event.
- Remove debris and sediment from the channel and rebuild the ridge as needed.
- Check outlets and make necessary repairs immediately.
- Remove sediment from traps or check dams when they are 50 percent full.
- When the work area has been stabilized, remove the ridge and fill in the channel to blend with the natural ground. Remove temporary slope drains and stabilize all disturbed areas with permanent vegetation or other erosion control practices.
- Remove the temporary deversion and stabilize the site stabilized *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).
- Maintain vegetation in channel as shown in the design plan.

Common Problems and Solutions

Problem	Solution
Seepage is encountered during construction.	It may be necessary to install drains.
Variations in topography on-site indicate diversion will not function as intended.	Consult with a registered design professional.
Design specifications for seed variety, seeding dates or erosion control materials cannot be met.	Substitutions may be required. Unapproved substitutions could result in erosion and lead to diversion failure.
Final discharges from diversion channels cause ongoing erosion at the outlets.	Modifications to the diversion system need to be made or energy dissipation devices installed.
Overtopping of channel; caused by sedimentation in channel resulting in grade decreasing or reversing.	Realign or deepen the channel to maintain grade.
Overtopping of ridge due to low point in ridge where diversion crosses a natural depression.	Build up ridge.
Erosion and scour of the channel; caused by high velocity in channel.	Consult a design professional and install velocity dissipators such as check dams.

Breach of ridge caused by uneven channel grade and leading to erosion in channel before vegetation is established.	Repair channel and add more effective erosion control option-erosion control blanket, turf reinforcement mat, transition mat, etc.
Poor vegetation establishment caused by seepage or poor drainage in channel.	Install subsurface drains or stone channel bottom.
Erosion in channel caused by excessive grade in channel.	Consult design professional, repair channel, install an erosion resistant lining and velocity dissipators such as check dams or realign to reduce the grade.
Erosion; caused by excessive velocity at outlet.	Consult a design professional, install an outlet stabilization structure (see Rock Outlets or Energy Dissipators).
Runoff from a storm event causes blow out failure; caused by ridge not being compacted.	Repair and use construction equipment to compact.

Right-of Way/Diversions Bars

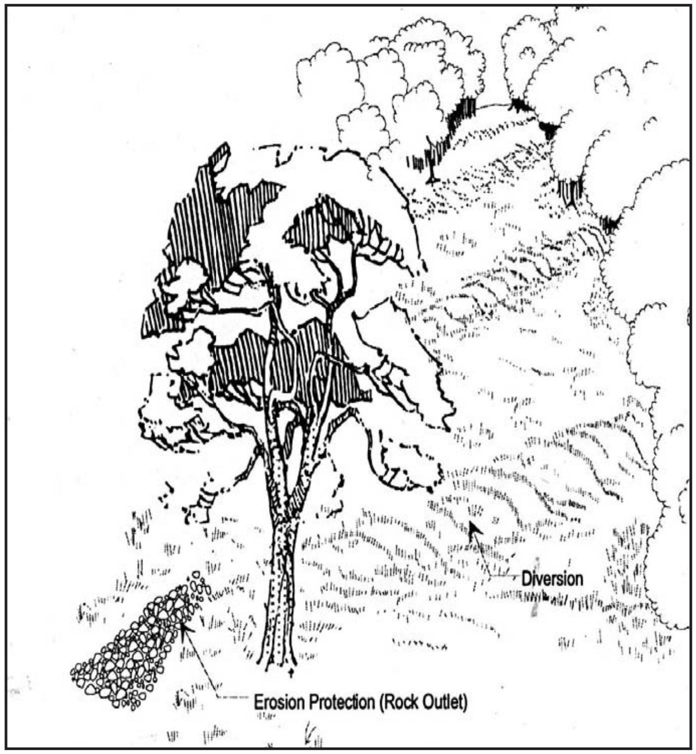


Figure 6.57 Typical Right-of-Way Diversion.

Practice Description

A right-of-way diversion, also known as a water bar, is a temporary ridge or combination of a ridge and excavated channel designed to shorten the flow length within a sloping right-of-way. The diversion thereby reduces the erosion potential by diverting storm runoff to a stabilized outlet. This practice applies to sloping right-of-ways or other long, narrow sloping areas such as utility access clearings.

Recommended Minimum Requirements

Prior to start of construction, right-of-way diversions should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The diversions should be built according to planned alignment, grade and cross section.

Height

18-inches.

Side Slopes

Side slopes are 2:1 or flatter; 3:1 or flatter where vehicles cross.

Base Width of Ridge

6-feet.

Spacing

Spacing as given in Table 5.14.

Grade

Stable, positive grade towards outlet, but less than 2 percent.

Outlet

Right-of-way diversion must cross full access width and extend to a stable outlet.

Table 6.15 Recommended Spacing of Water Bar Diversions

Slope	Diversion Spacing (ft.)
Less than 5%	125
5 to 10%	100
10 to 20%	75
20 to 35%	50
Greater than 35%	25

Source: *North Carolina Field Manual*, 1991

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Clear the access right-of-way and grade as necessary.
- Construct sediment traps or outlet stabilization structures as needed.
- After utilities have been installed in the corridor, locate the first bar at the required distance from the slope crest depending on steepness of the right-of-way slope (Table 5.14). Set the crossing angle so as to maintain a positive grade of less than 2 percent.
- Set the direction of the right-of-way diversions to use the most stable outlet locations. If necessary, adjust length of or spacing between bars to prevent runoff from upslope bars from merging with downslope water bar outlets.

Grading

- Mark the location and width of the ridge, and scarify the entire length.
- Excavate, fill and shape the diversion to planned alignment, grade and cross section.
- Fill the ridge to above the design height, then compact with rubber-tired equipment down to the design height.

Erosion Control

- Establish vegetation on the ridge and channel immediately following construction.

Construction Verification

- Verify the dimensions shown on the plans for height, base width, channel depth, grade and side slopes.
- Check all of the finished grades and configuration of all channels to eliminate constrictions to flow and to ensure the final discharge flows to sediment basins or stabilized outlets. Also check all ridges for low spots and stability.

Maintenance, Inspections and Removal

- Inspect right-of-way diversions weekly and after storm events for erosion and sediment deposition and periodically for vehicle wear.
- Remove debris and sediment from channels and sediment traps or basins.
- Repair ridges to grade and planned height.
- Add rock at crossing areas and stabilize outlets as needed.
- Repair and establish vegetation on right-of-way diversions immediately after installation of additional utilities in the right-of-way.
- To remove temporary right-of-way diversions, grade the ridge and channel to blend with the natural ground, compact the channel fill and establish vegetation on disturbed areas. (Do not remove right-of-way diversions until all disturbed areas draining to them are stabilized).
- Remove the temporary right-of-way diversion and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Gully erosion occurs between right-of-way diversions caused by diversion spacing being too wide for slope.	Install additional bars.
Ridge is worn down and channel is filled where vehicles cross caused by unstable surface.	Stabilize surface by using gravel or other surface treatment and reduce vehicle traffic.
Erosion at outlets caused by unstable outlet structures.	Install an outlet stabilization structure or extend the upslope bars so runoff will not converge on the lower outlets.
Erosion in channel caused by too steep of a grade.	Realign the right-of-way diversion to reduce grade.

Temporary Slope Drains

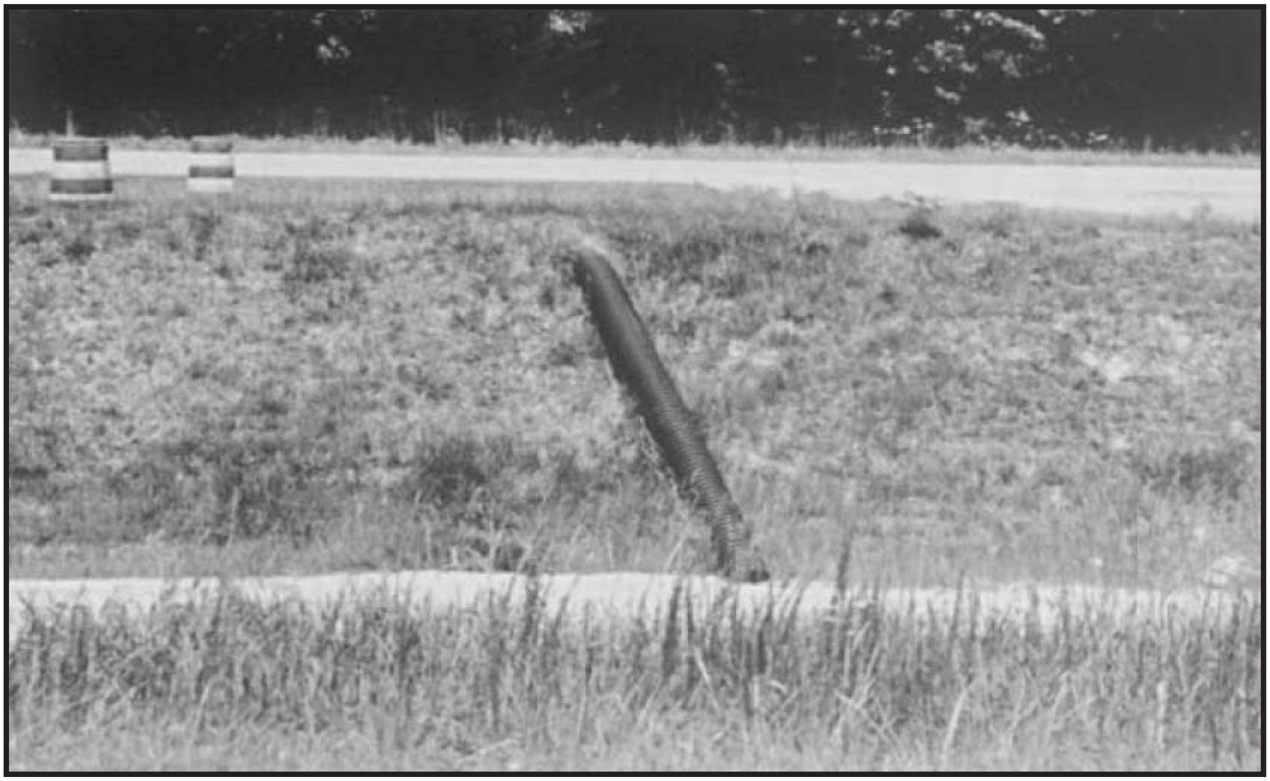


Figure 6.58 Temporary slope drains can be used almost immediately to carry surface runoff down a steep slope, allowing vegetation a chance to become established. Source: North Carolina Department of Environment and Natural Resources

Practice Description

A temporary slope drain is a pipe or other conduit designed to convey concentrated runoff down the face of a cut or fill slope without causing erosion. This practice applies wherever storm water runoff must be conveyed down a steep slope.

Prior to start of construction, temporary slope drains should be designed by a registered design professional. Plans and specifications should be referred to the job foreman and field personnel throughout the construction process.

Recommended Minimum Requirements

Material

Strong, flexible pipe, such as heavy-duty, non-perforated, corrugated plastic.

Design Life

18 months or less.

Inlet Section (optional).

Standard “T” or “L” flared-end section with metal toe plate.

Inlet to Pipe at Top of Slope

Compacted fill over pipe with minimum dimensions of 1.5-foot depth, 4-foot top width and 6-inches higher than ridge.

Outlet

Pipe should extend beyond toe of slope and discharge into a sediment trap or basin unless the contributing drainage area is stable or undisturbed. The pipe could also "T" with a perforated horizontal pipe discharging into a stable, vegetated area acting as a level spreader, turning concentrated flow into sheet flow.

Pipe Size

Refer to the appropriate design manual for your area (see Design Manual Reference).

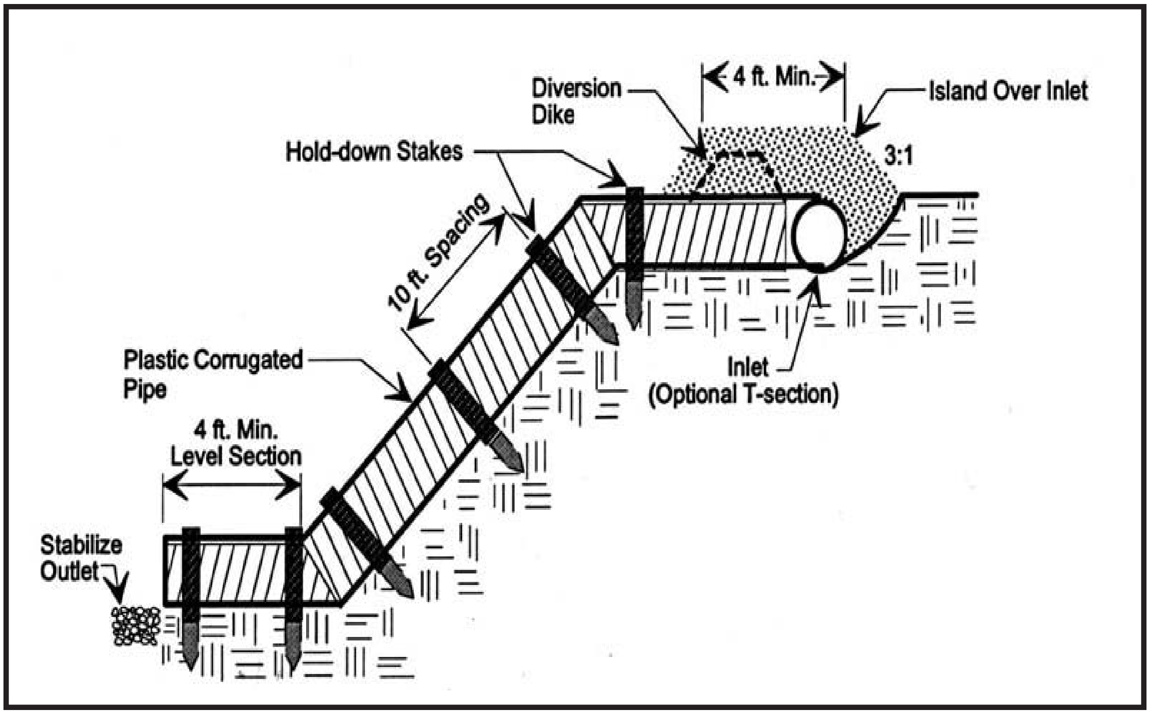


Figure 6.59 Typical Cross Section of Temporary Slope Drain with Optional T-section Inlet

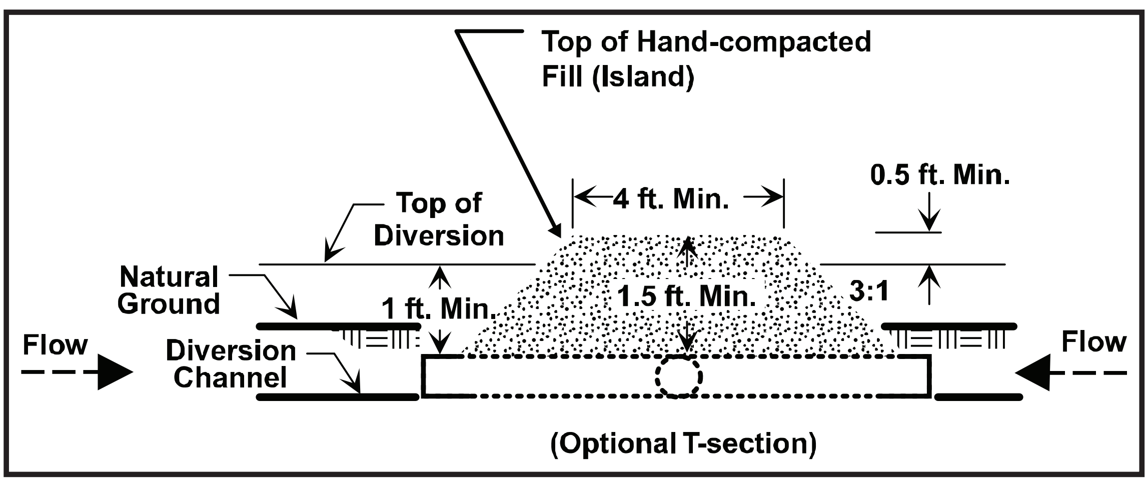


Figure 6.60 Detail of Inlet to a Temporary Slope Drain

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Place temporary slope drains on undisturbed soil or place well-compacted fill at locations and elevations shown on the plans.
- Grade the diversion channel at the top of the slope toward the temporary slope drain. A stable, positive grade not exceeding 2 percent is needed. Slightly slope the section of pipe under the ridge.
- Hand tamp the soil under and around the pipe in lifts not to exceed 6-inches.
- Ensure fill over the drain at the top of the slope has minimum dimensions of 1.5-foot depth (above top of pipe) and 1-foot top width.
- Ensure all slope drain connections are secure and watertight.
- Ensure all fill material is well-compacted. Securely anchor the exposed section of the drain with grommets or stakes spaced no more than 10 feet apart.
- Extend the drain pipe beyond the toe of the slope and adequately protect outlet from erosion.

Erosion Control

- Make the settled, compacted diversion ridge no less than 1 foot above the top of the pipe at every point.
- Immediately stabilize all disturbed areas following construction with vegetation or other appropriate means of protection.
- Provide for energy dissipation at the outlet of the pipe (see Energy Dissipators section.).

Construction Verification

- Verify the dimensions shown on the plans for the following: diameter of pipe, inlet, outlet elevations, orientation relative to how flow will enter the existing drainage pattern and diversion specifications (see Temporary Diversions).
- Joints should be carefully inspected for separations or looseness.

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate temporary slope drains will not function as intended.

Maintenance, Inspection and Removal

- Inspect slope drains and supporting diversions once a week and after every storm event.
- Check the inlet for sediment or trash accumulation; clear and restore to proper condition.
- Check the fill over the pipe for settlement, cracking or piping holes; repair immediately.
- Check for holes where the pipe emerges from the ridge; repair immediately.
- Check the conduit for evidence of leaks or inadequate anchoring; repair immediately.
- Check the outlet for erosion or sedimentation; clean and repair, or extend if necessary.

- After slopes have been stabilized, remove the temporary diversions and slope drains, and stabilize all disturbed areas.
- Remove the temporary slope drains stabilize the site prior to filing *Form H: Request for Termination of a General Permit, Form--MO 780-1409* (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Overtopping of the drain caused by undersized or blocked pipe; drainage area may be too large.	Install additional pipes and remove debris frequently.
Overtopping of the drain caused by improper grade of channel and ridge.	Regrade to provide positive drainage.
Overtopping of the drain caused by poor entrance conditions and trash buildup at pipe inlet.	Deepen and widen the channel at the pipe entrance; inspect and clear inlet frequently.
Erosion at outlet caused by focused erosive flow being released at too high an elevation.	Extend pipe to a stable grade or an outlet stabilization structure as needed.
Pipe separates or is displaced caused by lack of securement.	Tie the pipe down and secure the joints.
Animals going into the pipe outlet caused by open-ended pipe.	Install a free swinging animal guard.

Subsurface Drains

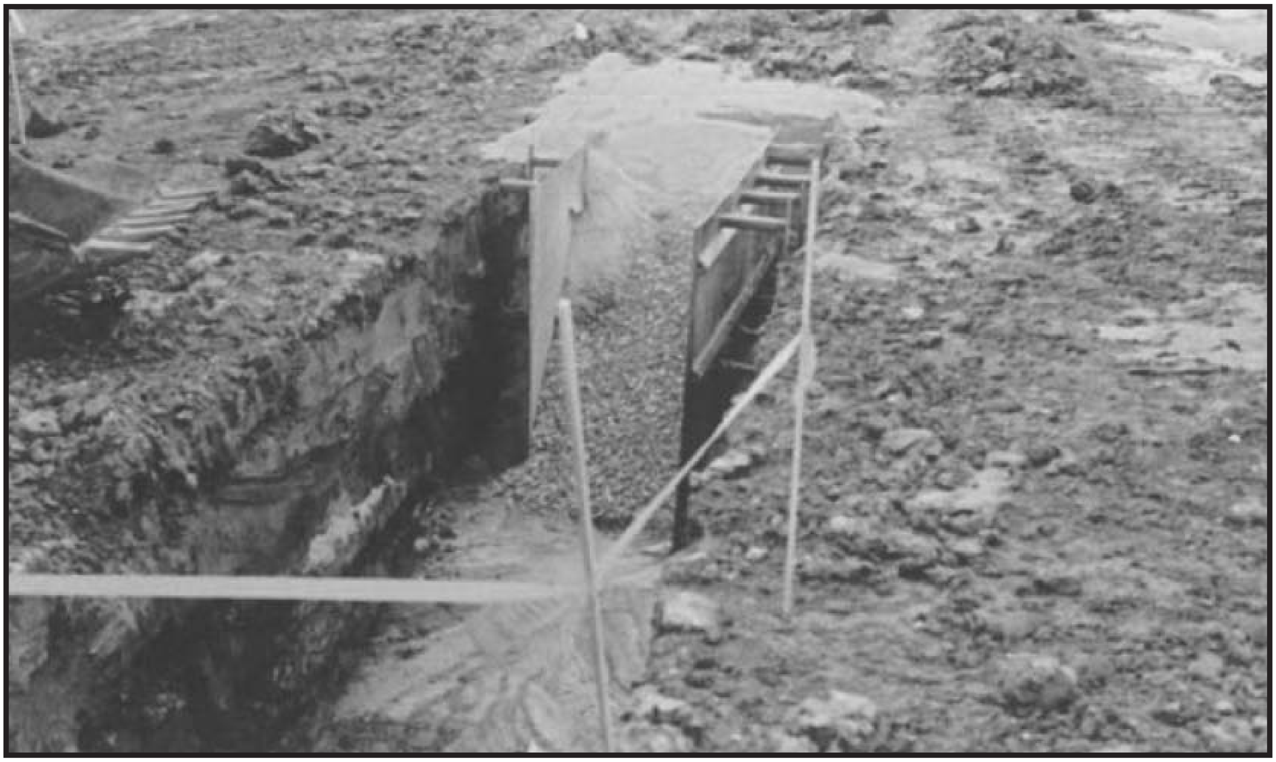


Figure 6.61 A gravel-filled trench is one of several ways to solve subsurface drainage problems. Note safety barrier around the trench.
Source: Bob Clay, Missouri Department of Natural Resources, Nodaway County

Practice Description

A subsurface drain is a perforated pipe or continuous layer of porous material installed below the ground surface that intercepts, collects and carries excessive groundwater to a stable outlet. Subsurface drains by themselves do not provide erosion control.

The purpose of a subsurface drain is to reduce storm water runoff volumes, and improve soil moisture conditions, vegetation growth and ground stability. Subsurface drains also prevent wet, soft ground from interfering with construction activities. Drains may be constructed using a gravel-filled trench, perforated pipe in gravel bedding or manufactured drain panel products. This practice applies where groundwater is at or near the ground surface or where adequate drainage cannot be provided for surface runoff.

Recommended Minimum Requirements

Prior to start of construction, subsurface drains should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Drainage system layout, depth, construction details and specifications should be included in the design plans. Some aspects of the design may depend on-site specific conditions not known or only estimated prior to installation and will need to be verified or modified during construction.

The timing of construction of these devices is critical. They should not be installed prior to final stabilization of the area where they will collect sediment laden runoff. Subsurface drains are not intended to collect sediment. If they do, they may become blocked or clogged and need to be reconstructed.

During the construction process, prior to final stabilization, infiltration trench excavations shall be completely protected from storm water runoff. These protection methods may include diversions, berms and other approved runoff barriers. Final placement of subsurface drain fill material and connection to the storm sewer system shall take place after the drainage area from which it receives water is completely stabilized.

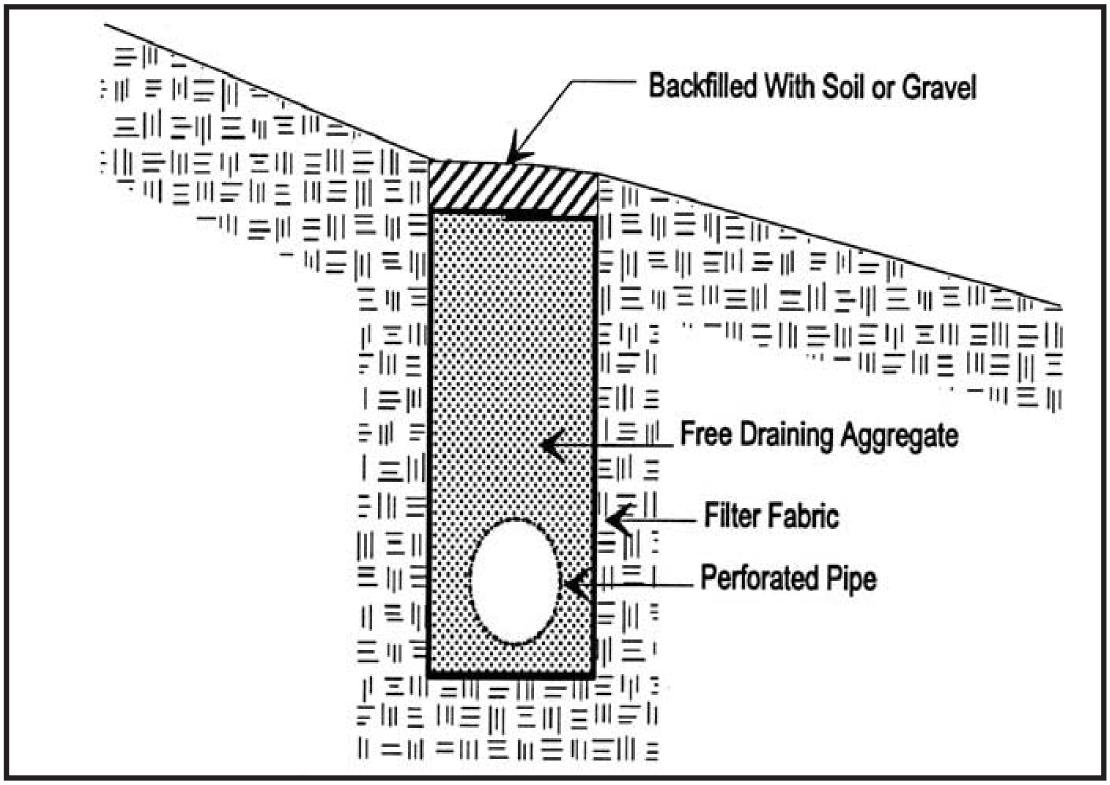


Figure 6.62 Typical Detail for Installation of Subsurface Drain

Layout and Depth
Generally, a depth of 3-feet and a spacing of 50 feet will be adequate.

Depth
Depth of the drain will determine how much the water table is lowered.

- Maximum: Limited by the impenetrable layer, and if pipe is used, by the allowable load on the pipe.
- Minimum: 2-feet under normal conditions.
- Spacing: Dependent on soil permeability and the depth of the drain.
- Multiple Drains: Determining the required spacing can be difficult. Install the first drain. Install an additional drain if seepage or high water table problems occur.

Location
Over 50 feet from the dripline of any trees.

Grade
Grade trench according to the design plan to prevent siltation within the drain. Steep grades should be avoided.

Gravel Bedding
Three inches or more of gravel placed completely around the drain and graded to prevent the infiltration of fine-grained soils into the drain.

Filter
As specified in design plan; determined by soil permeability. Usually filter fabric, although gravel bedding may be designed as a filter to prevent migration of fines.

Outlet
To a stable watercourse, with outlet above the mean water level in the receiving channel. Protect drains from erosion, undermining, damage from periods of submergence and the entry of small animals.

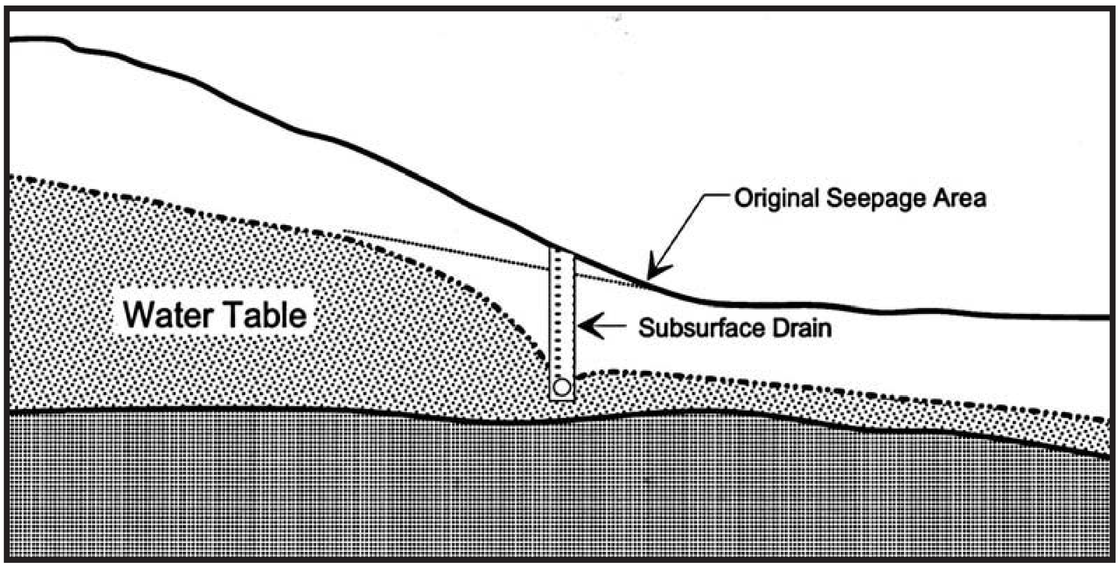


Figure 6.63 Detail of typical subsurface drain construction

Clean-outs
Required for long sections of drain.

Materials
Perforated, continuous closed-joint pipes of corrugated plastic, concrete, corrugated metal or bituminous fiber.

Strength and Durability
Should meet the requirements of the site in accordance with the manufacturer's specifications.

Construction
Installation
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Dig a trench to specified grade at least 3-inches (or as shown on the design) below the design bottom elevation of the pipe to accommodate the gravel bedding or filter material.
- Line trench with filter cloth, providing enough material to fold it back over the top of the finished gravel bedding. This helps prevent movement of soil into the gravel.
- Lay pipe on the design grade and elevation avoiding reverse grade or low spots. Do not use damaged, deformed, warped or otherwise unsuitable pipe.

- Place bedding material around pipe with at least 3-inches (or as shown on the design) of material on all sides. Place gravel around drains for proper bedding and improved flow of groundwater into the drain.
- Ensure gravel for bedding around flexible pipe does not exceed 3/4 inch in size to prevent damage to the pipe.
- Fold filter cloth over the top of the gravel bedding.
- Backfill immediately after placement of the pipe and bedding. Ensure the material does not contain rocks or other sharp objects and place it in the trench in a manner that will not damage or displace the pipe. Overfill the trench slightly to allow for settlement.
- Install clean-outs for maintenance as shown on the design plan.
- Construct the outlet above the mean water level in the receiving channel as shown in the design plan. For the outlet section of the drain, use at least 10 feet of non-perforated corrugated metal, cast iron, steel or heavy-duty plastic pipe. Cover at least 2/3 of the pipe length with well compacted soil.
- Place a suitable animal guard securely over the pipe outlet to keep out rodents.
- Cap the upper end of each drain with a standard cap made for this purpose, with concrete or with other suitable material to prevent soil from entering the open end.

Erosion Control

- Stabilize any soft, yielding soils under the drain with gravel or other suitable material.
- Keep the settled fill over the pipe outlet slightly higher than the surrounding ground to prevent erosion and wash out from surface runoff. Apply seed and erosion control to the fill as soon as installation is complete.
- Provide for energy dissipation at the outlet of the pipe (see Energy Dissipators section.)

Safety

Narrow trenches are subject to collapse and can be a safety hazard to persons in the trench. No person should enter a trench without shoring protection or properly sloping the sides of the trench. Follow Occupational Safety and Health Administration, or OSHA, guidelines for trench safety.

Construction Verification

- Verify the dimensions shown on the plans for the following: location and length, depth and cross section of trench.
- The dimensions and specifications of the aggregate used in the bedding and manufactured materials such as pipe, tile or panel drain should be verified.

Maintenance, Inspection and Removal

- Inspect subsurface drains periodically to ensure they are free-flowing and not clogged with sediment.
- Keep outlet clean and free of debris.
- Keep surface inlets open and free of sediment and other debris.
- Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain. Drains should not be located within the dripline of trees.
- Where drains are crossed by heavy vehicles, inspect the pipe to ensure it is not crushed.
- If this practice is temporary for construction only, it must be removed and the site stabilized prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate subsurface drains will not function as intended.
- Design specifications for aggregate or manufactured products cannot be met; substitutions may be required. Unapproved substitutions could result in failure of the drain to function as intended.
- Sediment discharges into the device clogging it; area draining to the subsurface drain must be stabilized prior to installing the drain.

Common Problems and Solutions

Problem	Solution
Poor drain performance; caused by bedding material that does not allow groundwater to free-drain or does not provide filtration for pipe.	Replace with properly graded material or filter fabric.
Poor drain performance; caused by pipe being crushed by construction traffic.	Replace damaged section of pipe.
Poor drain performance; caused by sediment clogging the pipe or gravel trench.	Stabilize area draining to trench, remove rock, clean out trench, reinstall pipe and clean the bedding material.

Rock Outlets

Figure 6.64 Riprap at the downstream end of a rock outlet should be level with the receiving channel or slightly below it .
It should not restrict the channel or produce an overfall that will result in scouring and erosion.
Source: Becky Holland, NRCS Volunteer. Jackson Co.

Practice Description

A rock outlet is a structure constructed to reduce and dissipate water energy in order to control erosion at the outlet of a channel or conduit. A rock outlet is an apron constructed of adequately sized rock riprap designed to prevent scour where storm water outlets a channel or conduit. It is also intended to minimize the potential for downstream erosion by reducing the velocity and energy of concentrated storm water flows.

This practice applies where the discharge velocity of a pipe, box culvert, diversion or other water conveyance structure exceeds the permissible velocity of the receiving area.

Recommended Minimum Requirements

Prior to start of construction, rock outlets should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The rock outlet should be built according to planned alignment, grade, cross section and length.

Grading

There should be a smooth transition between the rock outlet and the receiving channel; that is, the elevation of the rock apron at the downstream end should be at the same elevation as the bottom of the receiving channel.

Alignment

If possible, the alignment of the rock outlet should be straight throughout its length. If a curve is required, it should be located as closely as possible to where the flow enters the rock outlet.

Riprap

Riprap should consist of a well-graded mixture of rock (a range of sizes). Minimum and maximum rock size is dependent on volumes and velocities of storm water flows exiting the pipe. Larger rock should predominate, with sufficient smaller sizes to fill the voids between the rocks. The diameter of the largest rock size should not be greater than 1.5 times the d_{50} size (diameter of 50 percent of the rock).

Riprap Thickness and Length

Minimum thickness of riprap should be 1.5 times the maximum rock diameter. Length of riprap must be designed such that erosion at the outlet is minimal for receiving material.

Rock Quality

Select rock for riprap from field stone or quarry stone. The rock should be hard, angular and highly chemical and weather resistant. The specific gravity of the individual stones should be at least 2.5 times heavier than water.

High Tensile Strength Geotextile Fabric

Install between the rock riprap and the subgrade to prevent undermining of the structure due to piping of fine-grained subgrade soil.

Toewalls

According to the design plan; may be needed around full perimeter to prevent maintenance problems.

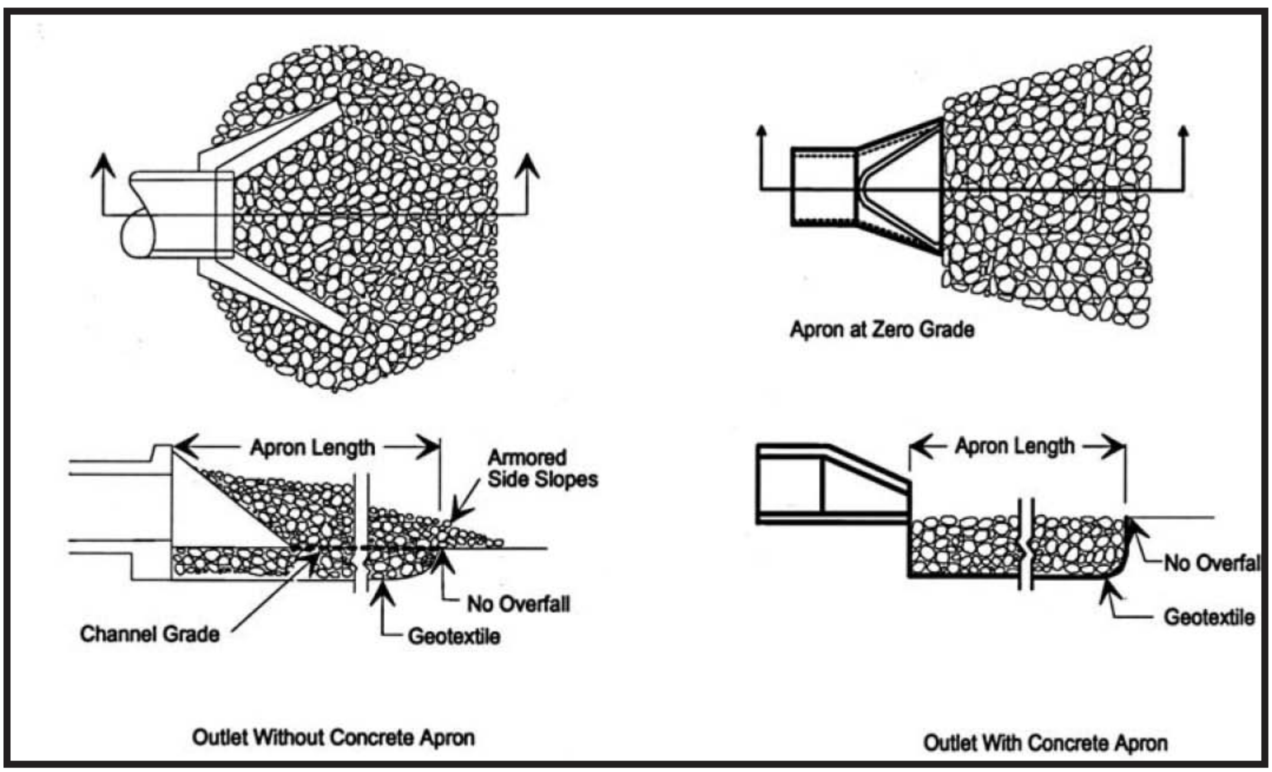


Figure 6.65 Typical rock outlet.

Construction

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Clear trees, stumps, brush, sod and all other unsuitable material that would interfere with construction of the rock outlet.
- Excavate the apron area subgrade below design elevation to allow for thickness of the filter layer and the riprap.
- Compact any fill used in the subgrade to the specified maximum density as determined by testing, and smooth enough to protect fabric (if used) from tearing.

Installation of Geotextile Filter

Place the geotextile fabric on the compacted smooth foundation. If more than one fabric piece is needed, the upstream piece should overlap the downstream piece by at least 1.5 feet in all directions. Staple geotextile fabric at the edges and overlaps to prevent movement during rip rap placement.

If the geotextile fabric tears when placing the riprap, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping the undamaged areas by at least 1.5 feet in all directions.

Installation of Riprap

- Install the riprap to the lines and elevations shown in the design. If there is no defined channel, the final cross-section should be level or slightly depressed in the middle; if well defined, the filter and riprap should extend to the top of the bank.
- Make sure the top of the rock apron is level with or slightly below the receiving stream. (Riprap should not restrict the channel or produce an overfall.)
- Blend the riprap smoothly to the surrounding grade.

Erosion Control

Stabilize all disturbed areas immediately following installation.

Construction Verification

- Check finished grade and configuration of structure.
- Check conformance of materials to specifications.

Maintenance, Inspection and Removal

- Inspect rock outlets after storm events for stone displacement and for erosion at the sides and ends of the apron.
- Make needed repairs immediately; use appropriate size stone, and do not place them above finished grade.
- If this practice is temporary for construction only, it must be removed prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements). Any land disturbance that occurs as a result of permanent retention or removal must be stabilized.

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on-site indicate rock outlet will not function as intended; changes in plan may be needed.
- Design specifications for riprap or geotextile cannot be met; substitution may be required. Unapproved substitutions could result in failure of the outlet.
- Rock is displaced downstream after storm event due to too small size of stone for the volume and velocities.

Common Problems and Solutions

Problem	Solution
Erosion around the apron and scour holes at the outlet; caused by foundation not excavated deep enough or wide enough or riprap restricts the flow cross section.	Remove filter and riprap, widen or deepen channel, replace filter and riprap.
Downstream erosion; caused by rock apron not on zero grade.	Modify grade or install grade stabilization measures at downstream edge of apron.
Rock displacement; caused by riprap installed smaller than specified.	Selective grouting over the rock materials may stabilize the situation, or replace riprap with larger size.
Downstream erosion; caused by riprap not extended enough to reach a stable section of channel.	Extend length of outlet.
Rock is displaced downstream after a storm event; rock is too small.	Needs to be redesigned.
Stone displacement and erosion of the foundation; caused by no filter installed under the riprap.	Remove riprap and install filter.

Compost Blankets, Berms and Socks

Compost has been viewed as a valuable soil amendment for centuries. Compost-enriched soil can also be used in practices that reduce erosion, control sediment runoff and alleviate soil compation. See Appendix G *Innovative Uses of Compost: Erosion Control, Turf Remediation and Landscaping*. EPA 350-F-97-043.

Compost Blankets

A compost blanket is a layer of loosely applied compost or composted material placed on the soil in disturbed areas to control erosion and retain sediment resulting from sheet-flow runoff.

Compost blankets can be placed on any soil surface:

- Rocky
- Frozen
- Flat
- Steep.

Figure 6.66 Applying a compost blanket in a new housing development. Source: Iowa Natural Resource Conservation Service, Urban Conservation Photo Gallery www.ia.nrcs.usda.gov/features/

The method of application and the depth of the compost applied will vary depending upon slope and site conditions. It can be used in place of traditional sediment and erosion control tools such as mulch, netting, or chemical stabilization. When properly applied, the erosion control compost forms a blanket that completely covers the ground surface. The compost blanket can be vegetated by incorporating seeds into the compost before it is placed on the disturbed area or the seed can be broadcast onto the surface after installation.

Compost blankets prevent storm water erosion by:

- Presenting a more permeable surface to the oncoming sheet flow, facilitating infiltration.
- Filling in small rills and voids to limit channelized flow.
- Promoting establishment of vegetation on the surface.

Compost blankets are most effective when applied on slopes between 4:1 and 1:1, such as stream banks; road embankments; and construction sites, where storm water runoff occurs as sheet flow. Compost blankets are not applicable for locations with concentrated flow. Because the compost is applied to the ground surface and not incorporated into the soil, a compost blanket provides excellent erosion and sediment control on difficult terrain, Including steep, rocky slopes.

Installation and Maintenance

- The compost should be applied to the soil surface in a uniform thickness, usually between 1- and 3-inches thick.
- The compost can be distributed by hand using a shovel or by mechanical means such as a spreader unit. The compost blanket should extend at least 3 feet over the shoulder of the slope to ensure storm water runoff does not flow under the blanket.
- Although seed can be broadcast on the compost blanket after installation, it is typically incorporated into the compost before it is applied, to ensure even distribution of the seed throughout the compost and to reduce the risk of the seed being washed from the surface of the compost blanket by stormwater runoff.
- In some applications, better sediment and erosion control can be achieved by using the compost blanket in conjunction with another best management practice, (e.g., lock-down netting, compost filter berms, or compost filter socks).

Figure 6.67 Applying a compost blanket on the side of a highway construction site. Source: *University of Georgia, Extension Learning, Bulletin 1200 Compost Utilization for Erosion Control*, May 2009

- Lock-down netting will help hold the compost in place, while compost filter berms or compost filter socks placed across the slope will slow down the flow of water. Compost filter berms or filter socks can also be placed at the top and bottom of the embankment.
- The compost blanket should be checked periodically and after each major rainfall.
- If areas of the compost blanket have washed out, another layer should be applied. In some cases, it may be necessary to add another storm water best management practice, such as a compost filter sock or sediment fence.
- On slopes greater than 2:1, establishing thick, permanent vegetation as soon as possible is the key to successful erosion and sediment control.
- Restricting or eliminating pedestrian traffic on such areas is essential.

Compost Filter Berms

Compost filter berms are contoured runoff and erosion filtration methods usually used for steeper slopes with high erosive potential. The berm allows runoff water to penetrate it and continue to flow while filtering sediment and pollutants from the water. It also slows the flow down, allowing soil particles to settle out. Berms work well in many of the same areas as blankets but are the preferred method if the slope exceeds a 4:1 gradient.

A compost filter berm is a dike of compost or a compost product placed perpendicular to sheet flow runoff to control erosion in disturbed areas and retain sediment. It can be used in place of a traditional sediment and erosion control tool such as a silt fence. The compost filter berm, which is trapezoidal in cross section, provides a three-dimensional filter that retains sediment and other pollutants while allowing the cleaned water to flow through the berm. Composts used in filter berms are made from a variety of feedstocks, (e.g., municipal yard trimmings, food residuals, separated municipal solid waste, biosolids and manure).

Figure 6.68 Source: University of Georgia, Extension Learning, *Bulletin 1200 Compost Utilization for Erosion Control*, May 2009

Compost filter berms are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat storm water that runs off as sheet flow. A filter berm also can be used as a check dam in small drainage ditches. The berms can be vegetated or unvegetated. Vegetated filter berms are normally left in place and provide long-term filtration of storm water as a post-construction best management practice. Unvegetated berms are often broken down after construction is complete and the compost is spread around the site as a soil amendment or mulch.

Filter berms installed to control erosion and sediment on a slope or near the base of a slope are trapezoidal in cross section, with the base generally twice the height of the berm. The height and width of the berm will vary depending upon the precipitation of the site. Modify the compost filter berm dimensions based on site-specific conditions, such as soil characteristics, existing vegetation, site slope and climate, as well as project-specific requirements.

Installation and Maintenance Activities

- The compost should be uniformly applied to the soil surface, compacted, and shaped to into a trapezoid. Compost filter berms can be installed on frozen or rocky ground.
- The filter berm may be vegetated by hand, by incorporating seed into the compost prior to installation (usually done when the compost is installed using a pneumatic blower or mixing truck with a side discharge), or by hydraulic seeding following berm construction. Proper installation of a compost filter berm is the key to effective sediment control.
- The compost filter berms should be inspected regularly, as well as after each rainfall event, to ensure they are intact and the area behind the berm is not filled with silt.
- Accumulated sediments should be removed from behind the berm when the sediments reach approximately one third the height of the berm.
- Any areas that have been washed away should be replaced. If the berm has experienced significant washout, a filter berm alone may not be the appropriate best management practice for this area.
- Depending on the site-specific conditions, the site operator could remedy the problem by increasing the size of the filter berm or adding another best management practices in this area, such as an additional compost filter berm or compost filter sock, a compost blanket or a silt fence.

Limitations

Compost filter berms can be installed on any type of soil surface. However, remove or cut down heavy vegetation to ensure the compost contacts the ground surface. Filter berms are not suitable for areas where large amounts of concentrated runoff are likely, such as streams, ditches or waterways, unless the drainage is small and the flow rate is relatively low.

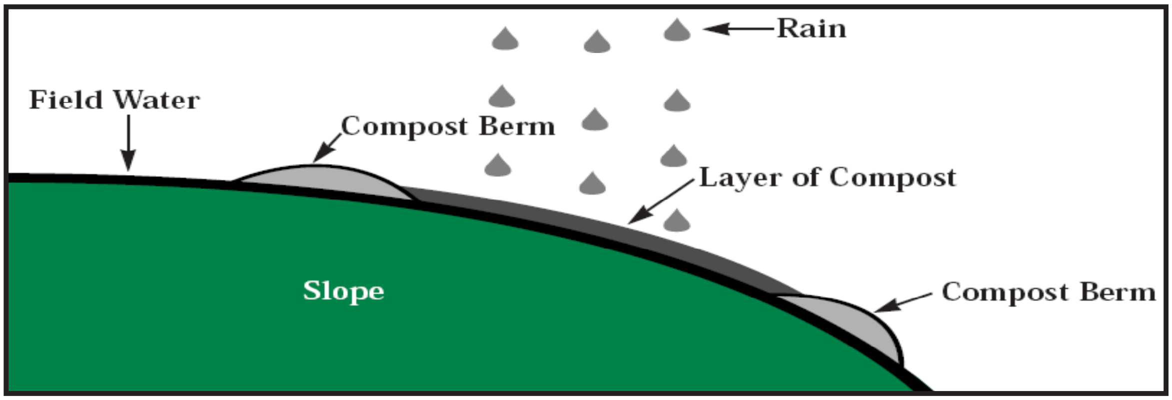


Figure 6.69 Source: *EPA Innovative Uses of Compost Erosion Control, Turf Remediation and Landscaping,* EPA530-F-97-043, Oct. 1997

Compost Filter Socks

Compost filter socks are applicable to construction sites or other disturbed areas where storm water runoff occurs as sheet flow. It is a mesh tube filled with composted material placed perpendicular to sheet-flow runoff to control erosion and retain sediment in disturbed areas. The compost filter sock, which is oval to round in cross section, provides a three-dimensional filter that retains sediment and other pollutants while allowing the cleaned water to flow through. Composts used in filter socks are made from a variety of feedstocks, including municipal yard trimmings, food residuals, separated municipal solid waste, biosolids and manure.

Compost filter socks offer a large degree of flexibility for various applications. To ensure optimum performance, remove or cut down heavy vegetation. Level extremely uneven surfaces to ensure the compost filter sock uniformly contacts the ground surface. Filter socks can be installed perpendicular to flow in areas where a large volume of storm water runoff is likely, but should not be installed perpendicular to flow in perennial waterways and large streams. Compost filter socks are often used in conjunction with compost blankets to form a storm water management system. Together, these two best management practices retain a very high volume of storm water, sediment and other pollutants.

Figure 6.70 Installation of filter socks in a road ditch by Indiana Department of Transportation. The filter socks will be staked through the center.
Source: *EPA NPDES Stormwater Menu of BMPs, Compost Filter Socks.*

Compost filter socks can be vegetated or unvegetated. Vegetated filter socks can be left in place to provide long-term filtration of storm water as a post-construction best management practice. The vegetation grows into the slope, further anchoring the filter sock. Unvegetated filter socks are often cut open when the project is completed and the compost is spread around the site as soil amendment or mulch. The mesh sock is then disposed of unless it is biodegradable.

Compost filter socks are generally placed along the perimeter of a site, or at intervals along a slope, to capture and treat storm water that runs off as sheet flow. Filter socks are flexible and can be filled in place or filled and moved into position, making them especially useful on steep or rocky slopes where installation of other erosion control tools is not feasible. There is greater surface area contact with soil than typical sediment control devices, thereby reducing the potential for runoff to create rills under the device or create channels carrying unfiltered sediment.

Common industry practice for compost filter devices is drainage areas do not exceed 0.25 acre per 100 feet of device length and flow does not exceed one cubic foot per second. Additionally, they can be laid adjacent to each other, perpendicular to storm water flow, to reduce flow velocity and soil erosion. Filter socks can also be used on pavement as inlet protection for storm drains and to slow water flow in small ditches. Filter socks used for erosion control are usually 12 inches in diameter, although 8 -, 18 - and 24-inch diameter socks are used in some applications.

Installation and Maintenance Activities

- No trenching is required; therefore, soil is not disturbed upon installation. After the filter sock is filled and put in place, anchor it to the slope. The preferred anchoring method is to drive stakes through the center of the sock at regular intervals; alternatively, stakes can be placed on the downstream side of the sock.
- Direct the ends of the filter sock upslope to prevent storm water from running around the end of the sock – meaning storm water should flow over the middle area of the filter sock. The sock should not create a dam that causes water to flow around it.
- The filter sock may be vegetated by incorporating seed into the compost prior to placement in the filter sock. The compost retains a large volume of water, which helps prevent or reduce rill erosion and aids in establishing vegetation on the filter sock.
- Inspect compost filter socks regularly, as well as after each rainfall event, to ensure they are intact and the area behind the sock is not filled with sediment.
- If there is excessive ponding behind the filter sock or accumulated sediments reach the top of the sock, add an additional sock on top or in front of the existing filter sock in these areas, without disturbing the soil or accumulated sediment.
- If the filter sock was overtopped during a storm event, the operator should consider installing an additional filter sock on top of the original, placing an additional filter sock further up the slope, or using an additional best management practice, such as a compost blanket in conjunction with the sock(s).

Transition Mats

Figure 6.71 Transition mat as an alternative to rip rap. Source: Erosion Tech LLC

Practice Description

A transition mat is a biotechnical alternative for rip rap. It is a mechanically-anchored 4 x 4 feet x .5 inch semi-rigid, polymer mat designed with voids throughout the structure that enables vegetative growth. Transition mats provide mechanical protection over highly-erosive areas, like storm water pipe outfalls, curb outfalls, over-flow structures and shorelines. Transition mats do not dissipate energy by impact, but mechanically protect the critical area until the high energy forces have dissipated as the storm flow exits further from the pipe discharge point. The resulting downstream forces are managed by appropriate soil covers calculated and specified as part of the transition mat engineered system. Transition mats provide resistance against much greater shear stress and velocities than vegetation alone or rock rip rap, and they are comparable in performance to Articulated Concrete Blocks. Vegetation provides many aesthetic, functional and synergistic benefits, but is not required for transition mat performance.

Recommended Minimum Requirements

Prior to start of construction, a vegetated occasional-overflow structure should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

- Transition mats must be used in combination over other soil covers:
    - Sod.
    - Sod and turf reinforcement mats.
    - Hybrid mats (e.g., geo-textile mat combinations where vegetation is unlikely).
- Design for the use of sod when feasible, to achieve the benefits of vegetation immediately. Design parameters prefer sod, or a combination of sod and transition mat in regions with adequate rainfall to ensure the best installation and performance possible.

- Specified anchors are essential to performance. Staples are not allowed. Anchor transition mats for consistent contact over the entire surface.
- Follow installation guidelines. Certified installers are preferred. Include an installation worksheet for each storm water outlet.
- See specifications for either cohesive or non-cohesive soils.
- Grade a level and smooth the soil surface at the scour area to avoid water concentration to create an appropriate base for the scour prevention measures. Install materials at or below the surface of the outlet. (The transition mat may be permanently attached over the surface of the discharge outlet.)
- Design for as much channel expansion as possible to help reduce velocities and increase infiltration potential.

Construction

Soil Cover Options

The transition mat has several installation types:

Type A - Over Sod

Most storm water pipe outlets and parking lot outlets are good applications for transition mats over sod. Sod provides immediate soil protection and eliminates any risk of poor seed germination.   Additional uses include occasional overflow structures and streambank protection preserving the natural landscape aesthetics.

Type B - Over Sod and Transition Mat

Transition mats over a sod and an open-weave transition mat combination for a higher level of protection, especially on slopes greater than 10 percent. Sod eliminates the germination issue of a plain transition mat installation. Appropriate locations would be 24- to 72+-inch storm water pipes, high flow parking lot outlets and streambank restoration.

Type C - Over a Transition Mat

Transition and transition reinforcement mats over bare soil (including composite mats). The flows should be less than 3-feet per second and the area fairly level to minimize concentrated erosive forces. A rural culvert outlet might be an appropriate application, or erosion protection at a temporary construction outlet. Maximum pipe size would generally be 24-inches for an open-weave mat, and up to 48-inches for a high-performance composite mat.

Type D - Over a Geotextile/Transition Mat

In a stream bed or shoreline application where vegetation is unlikely, or where vegetation may be delayed for whatever reason; use a 3 to 4 oz. geotextile for soil retention and soil protection under the transition mats. Above the normal-water line, use Type A or B to protect the slope bank from boat or wind wave erosion.

See manufacturer specifications for detailed installation guidelines.

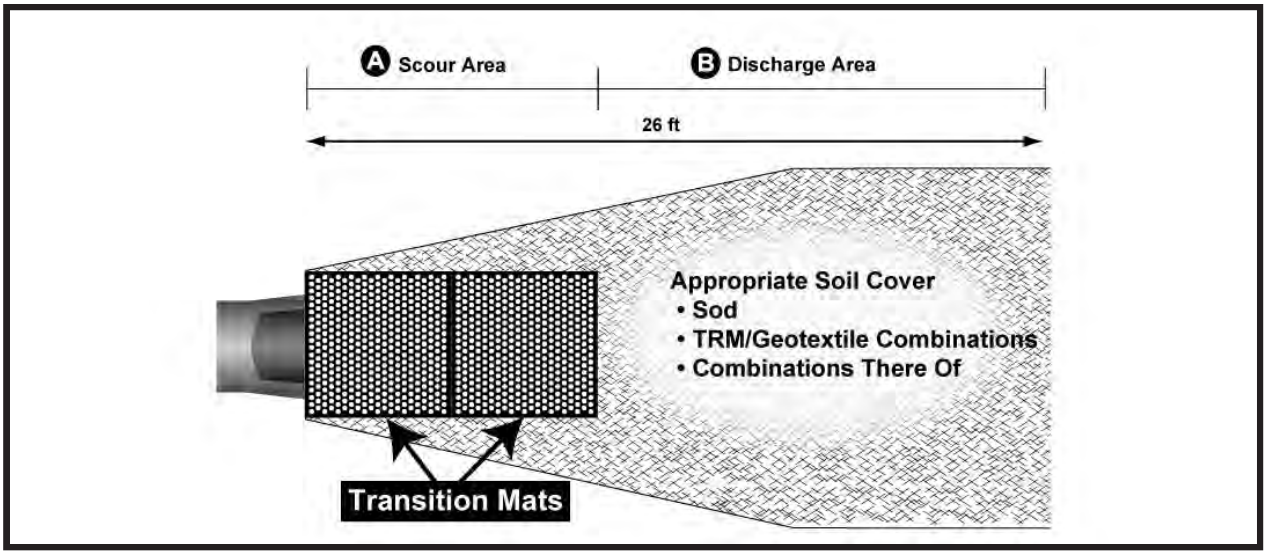


Figure 6.72 Transition Mat Detail Source: Erosion Tech LLC

Maintenance Inspection and Removal

- Transition mats are generally permanent installations, and maintenance should not be necessary.
- Until vegetation is established, inspect during construction on a weekly basis and after storm events. Remove accumulated sediment from the mat.

Troubleshooting

Consider sub-surface drainage for trickle flows, such as irrigation overcharge. Installations with continuous low flows, such as irrigation over charge, should use a sub-surface drainage system directly downstream of the outlet to drain that low flow from the surface, thus allowing vegetation to properly establish. Of course, an adequate slope is required for a sub-drain system.

- Calculate the downstream velocity and protect the channel using appropriate mats or sod. Mechanical flow dissipators or check dams may be appropriate during the germination period when seeding transition mats.
- Channel slopes restricting expansion require protection.
- Do not install at slope changes greater than 25 percent between the discharge area and the downstream channel that create impact or waterfall erosion.

Common Problems and Solutions

Problem	Solution
Erosion at the end or along sides of the mat; caused by insufficient mat size.	Consult a design professional and have new, larger mat installed.
Insufficient vegetation growth through mat; caused by inadequate or contaminated topsoil or trickle flows over saturating the soils.	Check soil below the transition mat for good topsoil, reseed and reinstall the turf reinforcement mat and transition mat.
Insufficient vegetation growth through mat; caused by poorly drained soil.	Consider installation or underdrain, reseed and reinstall the turf reinforcement mat and transition mat.

Temporary Sediment Trap

Figure 6.73 Sediment traps are used to collect sediment laden runoff from disturbed areas on construction sites. Source: EPA

Recommended Minimum Requirements

Prior to start of construction, sediment traps should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The sediment traps should be built according to planned grades and dimensions.

Location

- Where access can be maintained for sediment removal and proper disposal.
- Where runoff can be directed into basin at low velocity.

Drainage Area

- Below areas less than 5 acres in size. If the drainage area is larger, construct a sediment basin (see Sediment Basin).
- In the approach to a storm water inlet located below a disturbed area as part of an inlet protection system.
- Where failure of the structure will not result in loss of life, damage to homes, commercial or industrial buildings, main highways or railroads; or in the use or service of public utilities.

Structure Life

Limited to 18 months.

Sediment Storage
A minimum of 3,600 cubic square per acre of drainage area or sufficient to safely pass run-off greater than the two year frequency, 24-hour duration or design storm event.

Embankment
Dam Height
Less than five feet.

Top Width
At least five feet.

Fill Slopes
2.5:1 or flatter.

Settlement
10 percent or less.

Fill Material
Locally available soil; machine compacted in 8-inch lifts; moist when compacted; free of organic material, tree roots and waste material.

Spillway
A rock-lined open channel spillway should be constructed in the embankment to safely pass stormwater runoff. As an option, a perforated outlet riser can be used as the principal spillway.

Capacity
Sufficient to safely pass runoff from the two year frequency, 24-hour duration or design storm event.

Bottom Width
At least five feet.

Crest
A minimum of 18-inches lower than the top of the embankment.

Outlet
Include an apron at least five feet long to dissipate energy.

Filter
Geotextile should be placed between the embankment soil and the rock in the spillway section.

Construction
Site Preparation
- Locate the temporary sediment trap in an upland area as close to the sediment source as possible, considering soil type, pool area, dam length and spillway conditions.
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements on impoundment sites.
- Clear, strip and grub the foundation of the dam to minimum depth of 4-inches, removing all woody vegetation, rocks and other objectionable material. Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Divert off-site run-on from all undisturbed areas away from the sediment trap.
- Excavate the sediment trap (if necessary), stockpiling and stabilizing any surface soil having high amounts of organic matter for later use.

Embankment

- Scarify the base of the embankment before placing fill.
- Use fill from predetermined borrow areas. Fill should be clean, stable mineral soil free of organics, roots, woody vegetation, rocks and other debris, and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Compact the fill material in 8-inch continuous layers (maximum) over the length of the dam. (One way is by routing construction equipment over the dam so each layer is traversed by at least one wheel of the equipment.)

Open Channel Spillway

- Excavate a trapezoidal outlet section in the compacted embankment.
- Install geotextile fabric on the base of the channel, extending it up the sides to the top of the embankment.
- Place specified stone to the lines and grades, working smaller stones into voids to achieve a dense mass. The spillway crest should be level with a minimum width of five feet.
- Construct a stone outlet apron below the toe of the dam on level grade until a stable condition is reached (5-feet minimum).
- The base of the stone outlet should be at least two feet thick.
- Make the edges and end of the stone apron section flush with the surrounding ground.
- Cover the inside face of the stone outlet section with a 1-foot layer of well graded stone (2-inch minus).

Set a clean-out measurement stake in the basin at a height equal to one-half the distance from the bottom to the spillway crest.

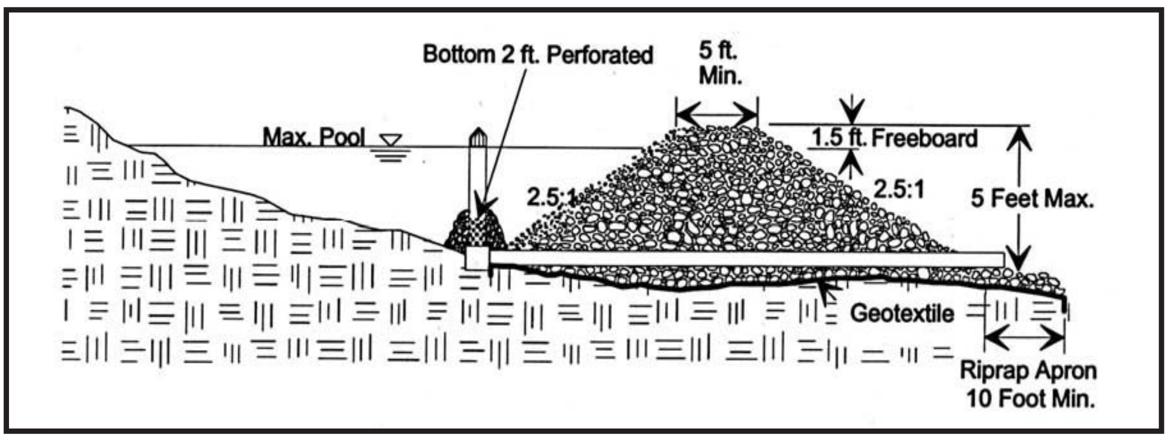


Figure 6.74 Temporary Sediment Trap with Spillway Riser

Optional Spillway Riser Construction

- Clear all vegetation and roots from the pipe foundation; prepare the bedding.
- Situate the spillway pipe and riser (minimum 18-inch diameter) on a firm, even foundation.
- Align the pipe and construct with the bell end of the pipe facing upstream. Around the barrel, place a 4-inch layer of moist, clayey, workable soil (not pervious material, such as sand, gravel, or silt), and compact with hand tampers to at least the density of the foundation soil. Don’t raise the pipe from the foundation when compacting under the pipe haunches. Connect the pipe to the riser.

- Perforate the bottom 2 feet of spillway riser with 1/2 inch diameter holes spaced 3-inches apart (or use a manufactured perforated riser) for draining the sediment trap. Wrap the riser with geotextile fabric.
- Embed the riser at least 12-inches into concrete. The weight of the concrete should balance the buoyant force acting on the riser. Buoyant Force = Volume of Riser x 62.4 lbs./ft.^{3}
- Surround the entire riser with two feet of clean uniformly graded stone.
- At the pipe outlet, install a riprap apron at least five feet wide and 10 feet long. The riprap should be a minimum of 6-inches in diameter (see Rock Outlets).
- Dewatering can also be accomplished with a skimmer (see Skimmers).

Erosion Control

- The size of disturbed areas should be minimized. Stabilize all disturbed areas immediately after construction. Establish vegetation and erosion controls within 14 days after construction is complete.
- Divert sediment-laden water to the upper end of the temporary sediment trap to improve trap effectiveness.
- Direct all runoff into the basin at low velocity.

Safety

Because temporary sediment traps will likely impound water, the following precautions should be taken:

- Avoid steep slopes; the slopes around the temporary sediment trap should be 2.5:1 or flatter; 3:1 if maintained by tractors or other machinery.
- Fence area and post warning signs if trespassing is likely.

Construction Verification

- Check finished grades and dimensions of the temporary sediment trap.
- Check materials for compliance with specifications.

Maintenance, Inspection and Removal

- Inspect the temporary sediment trap weekly and after each storm event.
- Remove and properly dispose of sediment on an upland area to dry and be stabilized when it accumulates to one-half the design volume, as indicated by the clean-out stake.
- Periodically check the embankment, spillway and outlet apron for erosion damage, settling, seepage or slumping along the toe, and repair immediately.
- Replace the spillway gravel facing if it becomes clogged.
- Inspect vegetation and reseed if necessary.
- Replace any displaced riprap, being careful no replacement rock is above the design grade.
- Remove the temporary sediment trap after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water, removing the sediment to a designated disposal area, grading the site to blend with the surrounding area; then stabilize.
- Remove the temporary sediment trap and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate sediment trap will not function as intended.
- Design specifications for fill, pipe, seed variety or seeding dates cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Common Problems and Solutions

Problem	Solution
Embankment overtopping and possible failure of the structure; caused by inadequate spillway size.	Increase size of spillway.
Overtopping and possible failure; caused by extensive embankment settling.	Add additional fill to bring embankment back to design grade.
Erosion and displacement of rock; caused by rock outlet apron not extending to stable grade.	Extend apron.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or rock size in spillway too small.	Improve vegetation, incorporate rolled erosion control product, or replace rock with larger size.
Settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Add fill in settled areas to restore embankment to original grade.
Structural failure; caused by inadequate compaction due to construction with dry soil.	Replace failed material and compact to original grade.
Slumping failure; caused by overly steep slopes.	Repair damage and flatten slope without reducing the storage volume.
Piping failure; caused by too steep of a slope between stone spillway and earth embankment.	Flatten slope, then repair piping damage.
Inadequate storage capacity; caused by sediment not being properly removed.	Remove sediment on a regular schedule.
Inadequate storage capacity; caused by having a greater are a contributing sediment than originally designed.	Stabilize the disturbed area contributing to the trap or regrade the construction site and add additional traps to better distribute sediment laden storm water among the traps to handle the sediment discharging to the drainage area.
Safety or health hazard; caused by ponded water due to sediment clogging the gravel on the upstream slope of the riprap.	Remove sediment and install security fence if necessary.

Energy Dissipators

Figure 6.74 Energy dissipators reduce flow velocities so water can exit at nonerosive rates. Source: C. Rahm, NRCS St. Charles Co.

Practice Description

An energy dissipater is a physical structure intended to reduce the erosive energy typically encountered down grade from a pipe or culvert. Erosive energy from intense flows may also be encountered in median ditches or road ditches. Energy dissipation may be accomplished by the installation of large boulders, wood pilings, engineered concrete structures or other means approved by the engineer. Unlike ditch checks and rock dams, energy dissipaters are not intended to impound water and sediment. Energy dissipaters must be constructed in a fashion such that the water that flows through, over or around the structure is equally distributed in the discharge channel and does not exacerbate or cause a resultant erosion problem.
(Source MoDOT 806.8)

Recommended Minimum Requirements

Prior to the start of construction, energy dissipators should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Capacity

Ten year peak runoff or the design discharge of the water conveyance structure, whichever is greater.

Size:

The energy dissipators should be specifically designed for the velocities and application. It must be long enough to dissipate runoff energy. The width should be designed to match the configuration of the receiving channel.

Riprap Structures

Apron

Should have zero grade with no overfall at the end of the apron.

Alignment

Should be straight throughout its entire length, but if a curve is necessary to align the structure with the receiving stream, locate the curve in the upstream section of the structure.

Riprap

Riprap should consist of a well-graded mixture of stone. Larger stone should predominate, with sufficient smaller sizes to fill the voids between the stones. The diameter of the largest stone size should be not greater than 1.5 times the d_{50} size.

Riprap Thickness

Minimum thickness of riprap should be 1.5 times the maximum stone diameter.

Stone Quality

Select stone for riprap from field stone or quarry stone. The stone should be hard, angular and highly chemical and weather resistant. The specific gravity of the individual stones should be at least 2.5 times heavier than water.

Filter

Install a filter to prevent soil movement through the openings in the riprap.

The filter should consist of a graded gravel layer or a synthetic filter cloth.

Concrete Structures

Requirements for concrete structures will vary according to the specific design configuration. The structure should conform to the dimensions, grades and alignments shown on the plans and specifications.

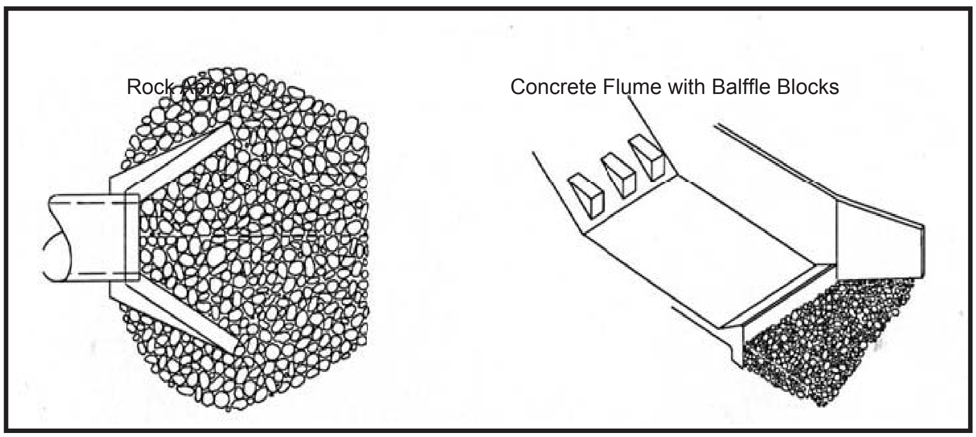


Figure 6.75 Common energy dissipators.

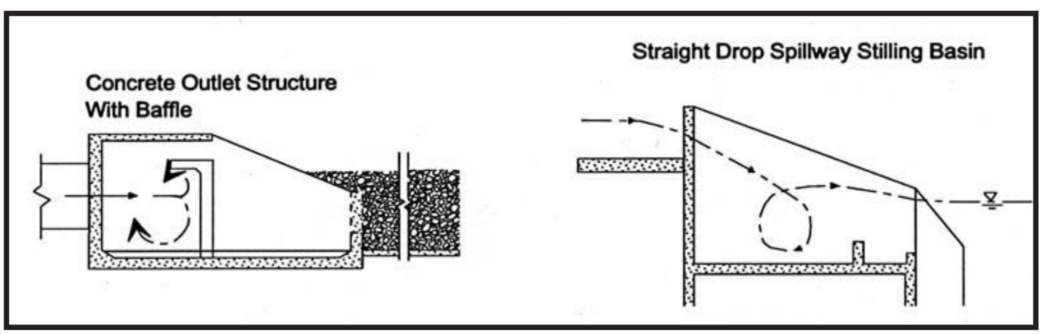


Figure 6.78 More Common Energy Dissipators

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Completely remove stumps, roots and other debris from the construction area. Fill depressions caused by clearing and grubbing operations with clean, non-organic soil.
- Grade the site to the lines and grades shown on the plans. Compact any fill required in the subgrade to the density of the surrounding undisturbed material.

Riprap Structures

- Ensure the subgrade for the geotextile and riprap follows the required lines and grades shown in the plan. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.
- Filter cloth must meet design requirements and be properly protected from penetration or tearing during installation. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet. If the damage is extensive, replace the entire filter cloth.
- Riprap may be placed by equipment. Care should be taken to avoid damaging the filter.
- Construct the apron on zero grade with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.

Concrete Structures

- Reinforcing steel should be placed in strict accordance with the design plans and maintained in the proper position during the pouring of concrete. Concrete should be placed in horizontal layers not exceeding 24-inches in thickness or as specified in the design, and consolidated by mechanical vibrating equipment supplemented by hand-spading, rodding or tamping.
- Concrete should be placed in sturdy wood or metal forms, adequately supported to prevent deformation. Forms should be oiled prior to placement to prevent bonding between concrete and forms.
- If possible, concrete should not be placed during inclement weather or periods of temperature extremes. If temperature extremes cannot be avoided, American Concrete Institute guidelines for placement of concrete during such extremes should be consulted.
- Concrete should be allowed to cure as called for in the plans and specifications. Typically, the surface should be kept wet during curing by covering it with wet burlap sacks or other means. Design strengths should be confirmed by laboratory tests on representative cylinders made during concrete placement. Form work should be left in place until the concrete attains design strength.

Erosion Control

Immediately after construction, stabilize all disturbed areas with vegetation.

Construction Verification

Check finished structures for conformance with design specifications.

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate energy dissipator will not function as intended.
- Design specifications for riprap, filter fabric, concrete, reinforcing steel or backfill cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance, Inspection and Removal

- Inspect riprap outlet structures weekly and after rain events to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Check concrete structures for cracks and movement. Immediately make all needed repairs to prevent further damage.
- These are permanent structures which are not removed when construction is complete unless the structure is temporary and also removed.
- If the energy dissipator is temporary for construction only, it must be removed prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Riprap Structures	
Erosion around the apron and scour holes at the outlet due to riprap restricting the flow cross section.	Remove filter and riprap, widen or deepen channel, replace filter and riprap.
Erosion at downstream end.	Modify grade or install grade stabilization measures at downstream edge of apron.
Rock displacement	Replace riprap with larger size.
Stone displacement and erosion of the foundation.	Remove riprap and install filter; replace riprap.
Concrete Structures	
Movement of base, cracking or complete failure of the concrete structures due to poor foundation preparation.	Inspect foundation thoroughly before concrete placement.
Excessive spalling, cracking or erosion of concrete surface due to concrete poured during inclement weather conditions.	Prohibit placement during inclement weather or follow accepted guidelines for such conditions.
Low strength, cracking, spalling or other undesirable conditions due to concrete not meeting specification.	Remove existing materials and reinstall after performing sufficient testing to verify concrete specifications.

Rock Check Dam

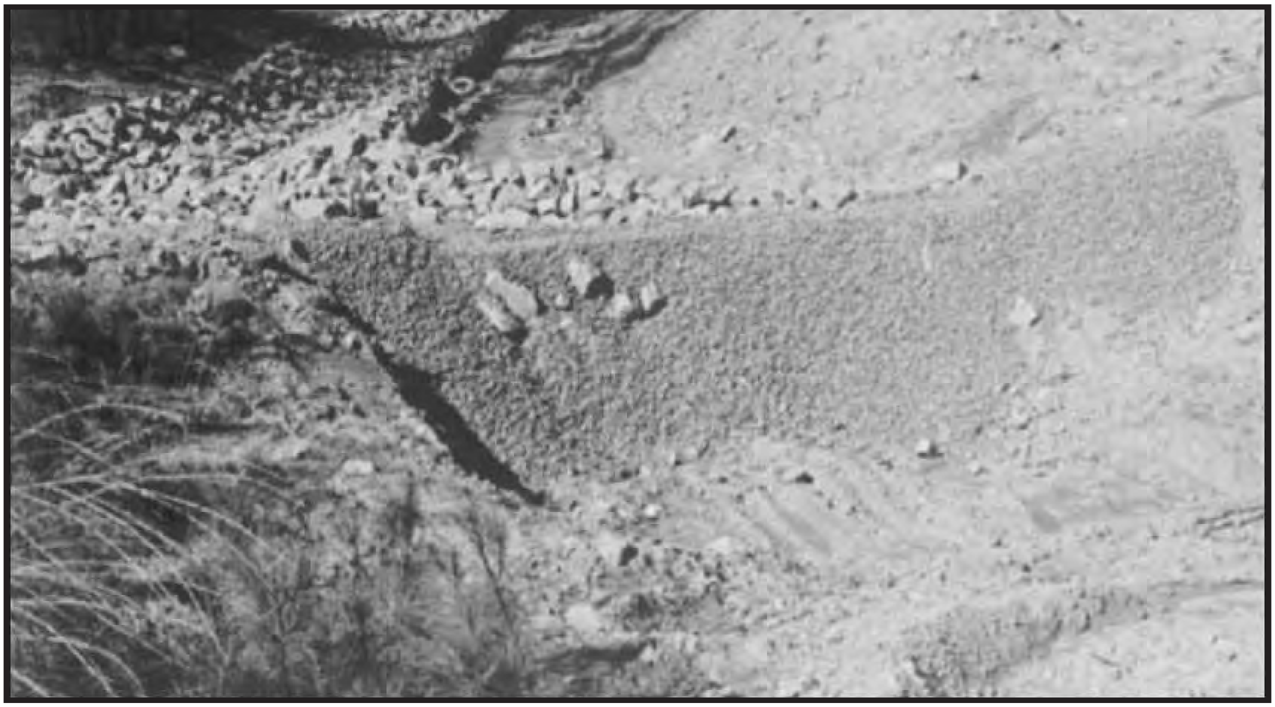


Figure 6.79 Rock check dams can provide sediment control in channels and swales.   Source ABC of BMPs, LLC

Practice Description

A rock check dam is a stone dam designed to capture sediment within drainage swales and diversions on the construction site. This practice can be used as an alternative to a standard sediment basin for locations with a drainage area of 20 acres or less. It may be preferred over standard sediment basins for sites where an earthen embankment would be difficult to construct.

Recommended Minimum Requirements

Prior to start of construction, rock check dams should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The rock check dam should be built according to planned grades and dimensions.

The major design elements include:

- Middle of the check dam is the lowest point where stormwater flow will go over the check dam. Make sure the ends are at a higher elevation than the middle.
- The downhill side slope of the check dam has a longer angle of repose to dissipate the energy of the stormwater flow over the dam to prevent scour on the downstream side of the check dam.
- The spacing between check dams is such that the bottom of the upper check dam is at the same elevation as the top of the check dam below it. This will not allow the stormwater flow to increase velocity as it goes down the slope but make the feature more like a stair step journey.

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Divert runoff from undisturbed areas away from the rock check dam and basin area.
- Do not divert toward existing buildings or houses.
- Stabilize the diversion, swale or channel with vegetation or a turf reinforcement mat to prevent or minimize erosion of the channel.

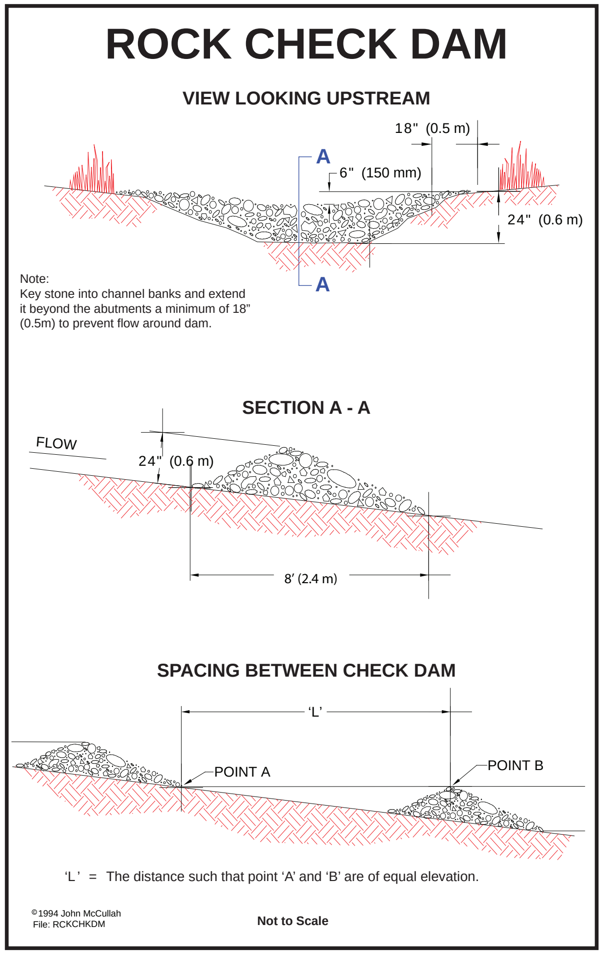


Figure 6.80 Detail of Rock Check Dam

Construct the check dams as shown in the Figure 5.89 and remember the following three design principals:

- The middle of the check dam is the lowest point so the storm water flow is directed to the middle of the channel.
- The down gradient side of each check dam is at a lower angle to allow for energy dissipation of the storm water flow over the check dam to reduce the potential for scour.
- Space the check dams so the elevation of the bottom of the upper check dam at the same elevation as the top of the lower check dam. This allows water to pond back to the check dam above it to reduce velocity and create a stair step cascade of the storm water flow.

Safety

Because rock check dam sediment basins impound water, they should be considered potentially hazardous. Take the following precautions:

- Avoid steep slopes; both cut and fill slopes should be 2.5:1 or flatter; 3:1 where maintained with tractor or other equipment.
- Fence area and post warning signs if trespassing is likely.
- Do not construct directly above structures that could be damaged in the event of failure.

Construction Verification

Check finished grades and dimensions of the rock check dam. Check materials for compliance with specifications.

Maintenance, Inspection and Removal

- Inspect the rock check dams weekly and after each storm event as required by your permit.
- Remove sediment when it accumulates to half the design volume.
- Check the dam and abutments for erosion, piping or rock displacement and repair immediately.
- If the channel does not drain between storms, replace the stone on the upstream face of the dam.

- After the construction site has become permanently stabilized:
  - Remove all temporary check dams and any unstable sediment.
  - Smooth the site to blend with the surrounding area and stabilize.
  - Remove all water and sediment from the basin prior to dam removal.
  - Place the sediment in designated disposal areas and is not allowed to flow into streams or drainage ways during structure removal.
  - Leave check dams in place if they are designed as permanent structures.
- Remove of this temporary rock check dam and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate the rock check dam will not function as intended.	Changes in plan may be needed, consult with a registered design professional.
Erosion increased during storm events; caused by the channel not being properly stabilized.	Stabilize the channel immediately with vegetation or turf reinforcement mat.
Storm flow goes around the sides of check dam eroding the bank; caused by the elevation of dam being too high in the middle.	Lower the middle of the check dam so storm water flow goes over the middle, repair damage and stabilize eroded side slopes.
Rock is displaced; caused by the stone size being too small or embankment slope is too steep.	Replace larger size stone or reduce slope.
Rock is displaced; caused by the high velocities because spacing between dams is too long and therefore does not rsufficiently reduce velocity.	Consult the design professional to recalculate the drainage slope and dam heights to determine correct check dam spacing.
Erosion occurs in downstream area; caused by the apron not extended to stable grade.	Repair erosion and extend apron.
Erosion of abutments occurs during spillway flow; caused by the rock not being high enough on the abutment.	Extend rock higher on the abutment.
Sediment is being carried through the spillway or accumulates in excess between clean outs; caused by the drainage area being too large.	Divert runoff from undisturbed areas way from the basin, enlarge basin and clean out basin more frequently or consult the professional designer for other alternatives.
Sediment is lost through the check dam; caused by the layer of gravel aggregate on the upstream face not being thick enough or is too coarse to restrict flow through the dam.	Replace gravel aggregate with material having proper gradation to provide filtration.

Ditch Checks

Figure 6.81 This check dam device appears to be working correctly but there should also be erosion control protection covering the channel to reduce scour and erosion of the channel bottom. Source ABC of BMPs, LLC

Practice Description

As with rock check dams, premanufactured ditch checks are used in water ways and swales to reduce water velocities in concentrated flows, dissipate energy to drop out larger sediment loads in fast moving water and reduce erosion in ditches until permanent, vegetation can be established. With routine maintenance, life expectancy is usually six and nine months.

Sediment fence and straw bales are generally not recommended for ditch checks. Suitable products include silt dikes, permeable plastic triangular berms and permeable M panels. In lighter flows use straw and excelsior wattles and compost socks. A critical component of any ditch check is that it does not cause more erosion on the downstream side than what it is protecting upstream. All channels should have erosion control practices in place such as blankets or turf reinforcement mats to further reduce scour and erosion of the channel.

Recommended Minimum Requirements

Drainage Area

The drainage area requirements are in direct relation to how wide the ditch or swale is and the strength of the ditch check. Hydraulic design is recommended to ensure proper material selection and placement.

BMP Lifespan

Six and nine months. Some will last longer.

Anchors
Vary by product type. Silt dikes require stapling with 6-inch staples(in fill conditions, 12- to 18-inches geotextile fabric pins are required) Permeable plastic berms require 10-inch landscape spikes. Permeable M panels require separate M-pins. Wattles and logs typically require 18- to 24-inch wood stakes on 2-foot centers.

Other Materials
A geotextile fabric is strongly recommended for any rock ditch check to separate the rock from the finished grade.

Location
A generally accepted standard for ditch check location is to locate ditch checks where elevation change from one check to the next is equivalent to the height of the particular ditch check used.

Construction
Site Preparation
Finish swale grading to plans. If swale is not in its final configuration, immediately install designed ditch check according to the manufacturer's requirements for effective sediment control. If swale is completed and ready for final stabilization, use the appropriate erosion control practice as designed by the engineer, then install ditch checks that will allow for vegetation establishment. A critical component of any ditch check is the elevation at the center of the check be lower than any other point. including the termination of the check into the side slope. At no time should water have the ability to flow around the ditch check.

Erosion Control
Erosion control measures should be used in conjunction with a ditch check. In many cases, effective erosion control can reduce the need for as many ditch checks on a project.

Figure 6.82 Wattle Ditch Check Source: American Excelsior

Construction Verification

The field inspector should:

- Verify the dimensions shown on the plans for the ditch location.
- Verify the top elevation as it relates to the termination at the sides.
- Verify the ditch check is properly secured to the ground surface.
- Evaluate stabilization techniques required for effective erosion control.
- Check all finished grades and final ditch check locations.

Maintenance, Inspection and Removal

- Maintenance includes periodic sediment removal after rain events to allow for maximum capacity of sediment. Each rain event will drop a significant amount of sediment. For rock ditch checks, complete removal of sediment laden rock and replacement with clean rock is required after the ditch check is plugged and ponds water. Geotextile may need to be replaced as well. If ditch checks become damaged from bed load and floating debris, replace as necessary.
- Remove temporary ditch check and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Erosion occurs into the side slope - water goes around ditch check.	Increase length of ditch check so lowest point is in center of channel or swale.
Significant erosion occurs between ditch checks - too much distance between ditch checks.	Install additional ditch check in between - follow recommended guideline for spacing.
There is poor erosion control on grade between ditch checks.	Re-grade, seed and apply appropriate erosion control practice.
There is scour on downstream side of ditch check-may be caused by too much water flowing in ditch or poor ditch check design for hydraulic condition.	Use alternative ditch check and install appropriate erosion control measure to reduce erosion on downstream side of ditch check.
Stormwater flow cuts around the ends of the ditch check.	Ditch check is lower at the ends than the middle and needs to be redesigned and installed properly.

Wattles

Figure 6.83 Wattles are used here as slope breaks to reduce the velocity of overland flow. Source: Missouri Department on Natural Resources Southwest Regional Office

Definition and Purpose

Wattles are degradable or nondegradable materials rolled or bound into a tight tubular roll and placed on the toe and face of slopes to intercept runoff, reduce flow velocity, release the runoff as sheet flow and provide removal of sediment from the runoff. Wattles may also be used for inlet protection and as check dams under certain situations. A degradable wattle consists of wood excelsior, rice or wheat straw, or coconut fibers. Nondegradable wattles consist of recycled tire products, foam peanut material or other material bound in a heavy mesh tube.

Recommended Minimum Requirements

This Best Management Practice may be implemented on a project-by-project basis with other best management practices when determined necessary and feasible. Wattles may be used:

- Along the toe, top, face and at grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow.
- Below the toe of exposed and erodible slopes.
- As check dams in drainage swales.
- For drain inlet protection.
- Down-slope of exposed soil areas.
- Along the perimeter of a small area (less than 1/3 acre) such as home lot.

Construction

- Runoff and erosion may occur if the wattle is not adequately trenched in.
- Wattles must be overlapped along the edges of at least 12-inches.
- Wattles at the toe of slopes greater than 1:5 may require the use of 500 mm (20" diameter) or installations achieving the same protection (e.g., stacked smaller diameter fiber rolls, etc.).
- Wattles may be used for drainage inlet protection if they can be properly anchored.
- Degradable wattles are somewhat difficult to move once saturated.
- Wattles could be transported by high flows if not properly staked and trenched in place.
- Wattles have limited sediment capture zone.
- Do not use wattles on slopes subject to creep, slumping or landslide.

Maintenance, Inspection and Removal

- Inspect wattles each week and after rain events as required by your permit.
- Clean accumulated sediment from behind wattles prior to the next rain event.
- Maintain wattles to provide an adequate sediment holding capacity. Sediment shall be removed when the sediment accumulation reaches one-half of the barrier height. Removed sediment shall be incorporated in the project or disposed in accordance with Missouri State solid waste regulations.
- Remove wattles as soon as possible after the project site has been stabilized. Dispose of in accordance with solid waste regulations and permit requirements.
- Remove the temporary wattles and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Erosion and rills form under the wattle; caused by the wattle not being properly trenched into the ground.	Repair erosion, fill rills and trench wattle properly.
Erosion around edges of the wattle; caused by the wattle not placed on the contour with a slight up gradient at the edges.	Reinstall wattles on the contour with a slight turn up gradient at the edges.
Erosion at the joints of two wattles; caused by the wattles not being properly overlapped.	Reinstall wattles with overlap of the edges at least 12-inches.

Straw Bale Barrier

Practice Description

This barrier is a temporary row of entrenched and anchored straw bales. This practice applies downstream of very small disturbed areas of one acre or less subject to sheet erosion. The purpose is to intercept and detain small amounts of sediment in order to prevent sediment from leaving the construction site. EPA does not recognize straw bale barriers as an effective best management practice and many areas of Missouri are phasing out their use.

Recommended Minimum Requirements

Prior to start of construction, straw bale barriers should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The straw bale barrier should be built according to planned grades and dimensions.

Drainage Area

Areas subject to sheet erosion: from one acre or less.

Bale Size

14-inch x 18-inch x 36-inch (no seed).

Anchors

Two 36-inch long (minimum) 2 x 2 inch hardwood stakes driven through each bale.

Slopes

4:1 above the barrier; with maximum drainage area of one acre or less.

Effective Life

Less than three months.

Location

On nearly level ground. The barrier should follow the land contour as closely as possible. Not in live streams or in swales where there is the possibility of a washout. Not in areas where rock or another hard surface prevents the full and uniform anchoring of the barrier.

Restricted Use

When used as a best management practice, straw bales shall be replaced after 60 days or sooner if failure is imminent. Straw bales shall be used as a solution only as a last alternative. The date the straw bales were installed shall be recorded on the weekly Storm Water Pollution Protection Plan inspection report.

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Grade alignment of barrier as needed to provide broad, nearly level area upstream of barrier.

Grading

- Excavate a trench at least 4-inches deep, a bale's width, and long enough the end bales are somewhat upslope of the sediment pool (Fig. 5.87).
- Place each bale end to end in the trench so the bindings are oriented around the sides rather than top and bottom (Fig. 5.87).
- Anchor the bales by driving two 36-inch long 2 x 2 inch hardwood stakes through each bale until nearly flush with the top. Drive the first stake toward the previously laid bale to force the bales together. Ensure there are no gaps between bales.
- Wedge loose straw into any gaps between the bales to prevent sediment-laden water from running through.
- Backfill and compact the excavated soil against the bales to ground level on the down slope side and to 4-inches above ground level on the upslope side.

Erosion Control

Stabilize disturbed areas in accordance with the vegetation plan.

Construction Verification

Check finished grades and dimensions of the straw bale barrier. Check materials for compliance with specifications.

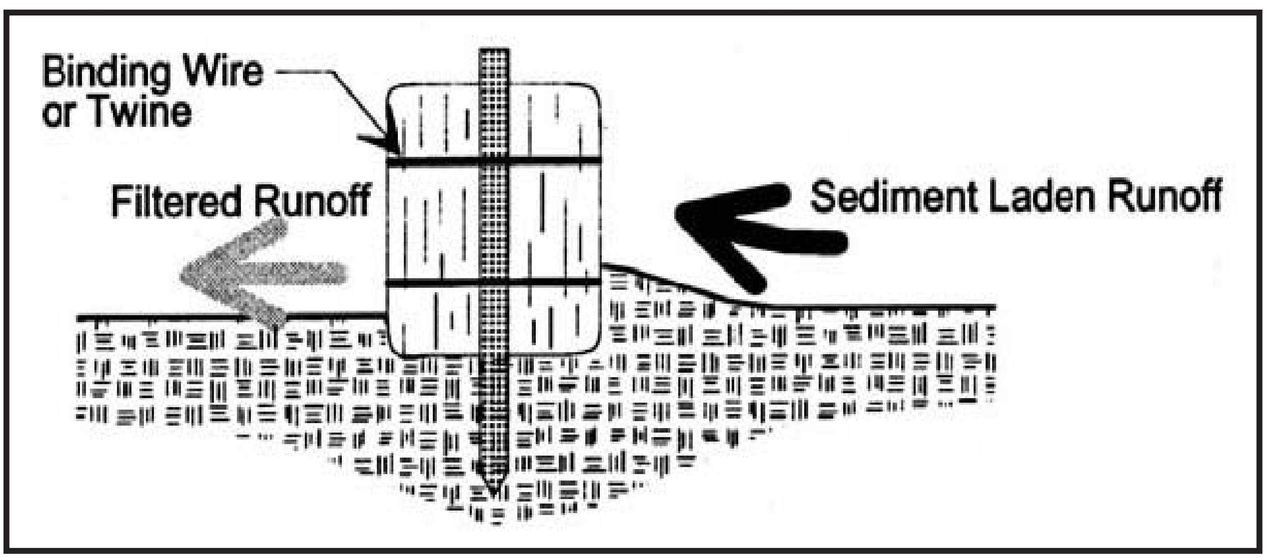


Figure 6.84 Installation of straw bales.

Maintenance, Inspection and Removal

- Inspect straw bale barriers weekly and after each storm event as required by your permit.
- Remove sediment deposits promptly, taking care not to undermine the entrenched bales.
- Inspect periodically for deterioration or damage from construction activities. Repair a damaged barrier immediately.
- After the contributing drainage area has been stabilized, remove all straw bales and sediment. Bring the disturbed area to grade and stabilize.
- Removal of this temporary device must be performed and the site stabilized prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

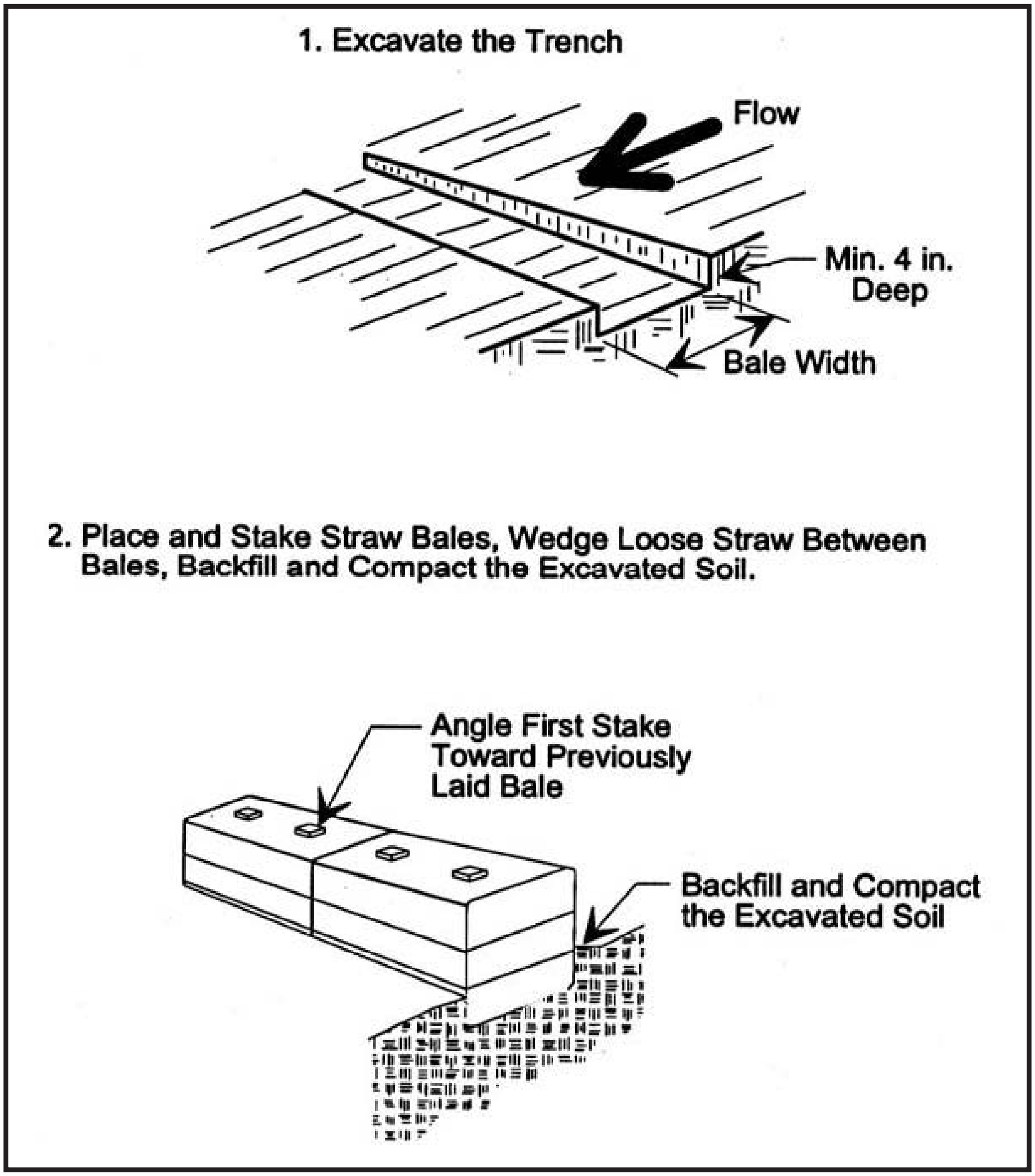


Figure 6.85 Straw bale alignment.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate sediment fence will not function as intended.	Changes in plan may be needed.
Erosion under or around end of bales; caused by the barrier terminating at an elevation below the top of the temporary pool or at an unstabilized area, is located on too steep a slope or was placed in an area of concentrated flow.	Correct problem by re-grading or stabilization; if straw bale barrier is in area of concentrated flow, use different method of sedimentation control (see Rock Check Dam or Ditch Check).
Overtopping of barrier; caused by inadequate storage capacity, no provision was made for safe bypass of storm flow, or the drainage area is too large.	Reduce the area draining to the straw bales or use device other than straw bales.
Unsightly after project stabilization; caused by bales not removed after area has been stabilized.	Remove in a timely manner and stabilize the disturbed area.
Undercutting of barrier; caused by bales not entrenched at least 4-inches or backfilled with firmly compacted soil.	Reinstall barrier using proper installation methods.
Collapse or dislodge of barrier; caused by bales not adequately staked.	Reinstall barrier using proper installation methods.
Collapse or dislodge of barrier; caused by too much sediment allowed to accumulate between clean outs.	Remove accumulated sediment more frequently.

Vegetative Buffer Strip

Figure 6.86 Vegetative buffer strips slow surface runoff, reduce sedimentation and help capture pollutants. Depending on the choice of plant materials, they can be low maintenance areas (mow once or twice a year) or provide habitat for wildlife.

Practice Description

A vegetative buffer strip is a wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants and reduce stormwater flow and velocity. Vegetative buffer strips are similar to grassed swales except they are designed to accept only overland sheet flow. They cannot treat high velocity flows. Surface runoff must be evenly distributed across the vegetative buffer strip. After a channel forms in the vegetative buffer strip, it is no longer effective.

Vegetative buffer strips can consist of grass, woody vegetation or other erosion resistant plants. They can be used adjacent to impervious surfaces and next to stream corridors or wetlands to slow the flow and help remove sediment from runoff. They can also be used in conjunction with infiltration basins, infiltration trenches or alongside streams to provide water quality treatment for post-construction.

Recommended Minimum Requirements

Prior to start of construction, vegetative buffer strips should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The vegetative buffer strip should be built according to planned alignment, grade and cross section. Should any field adjustment to the design and installation be needed, a qualified professional should be consulted in the modification to the original design or specification.

Drainage Area

Less than 5 acres.

Location

Adjacent to low or medium density residential areas on gently sloping ground (less than 5 percent), with length of strip running along the contour, along the perimeter of a site, or any available vegetated area or area capable of being vegetated.

Vegetation

A mix of erosion resistant plants that form a dense mat and effectively bind the soil (see Permanent Seeding).

Slope

Uniform, even and relatively flat (5 percent or less) with a level spreading device (level lip, weir, etc.) across the top edge of the vegetative buffer strip.

Minimum Width

Should conform to those in Table 6.16.

Minimum Length

At least as long as the contributing runoff area, but no less than 50 feet plus 4 feet for each one percent increase in slope.

Table 6.16 Minimum Width of Vegetative Buffer Strip

Slope of Land	Width of Vegetative Buffer Strip	Width of Vegetative Buffer Strip
(Percent)	For Grassed Areas (ft.)	For Forested Areas (ft.)
0	10	25
2	12	29
4	14	33
6	16	37
8	18	41
10	20	45
15	25	55

Construction

Site Preparation

- Natural wooded strips in addition to grass strips should be considered. At the start of development, designate, identify and fence off any areas to be preserved. Avoid storing debris from clearing and grubbing activities and other construction waste material in these areas during construction.
- If a vegetative buffer strip is constructed, clear and grub the vegetative buffer strip area before the impervious area is completed.

Grading

- If the adjacent area does not meet the buffer on a uniform contour, grade a swale along the contour directly adjacent to the top edge of the vegetative buffer strip. The swale will serve as a "level spreader" to collect overland flow and distribute the runoff evenly to the vegetative buffer strip. By discharging to the vegetative buffer strip uniformly along the top of the strip, rill and gully formation due to concentration of flow is minimized.
- Line the swale with rock or other erosion resistance material.
- Sod or seed, fertilize and protect the vegetative buffer strip area with an appropriate rolled erosion control product per the specifications.

  Note: Some fertilizing activities may be prohibited near wetlands and other eco-sensitive areas. Consult a qualified professional if needed.
- Vegetated buffer strips should be protected from excessive sediment laden storm water runoff during construction operations because excess sediment will kill the vegetation. This protection can be in the form of silt fence or other sediment control best management practices placed at the top of the slope to pretreat runoff headed for the buffer strip. If excessive sediment is deposited in the buffer strip, appropriate measures should be taken to reestablish the vegetative strip, including complete regrading and reseeding or sodding of the area.

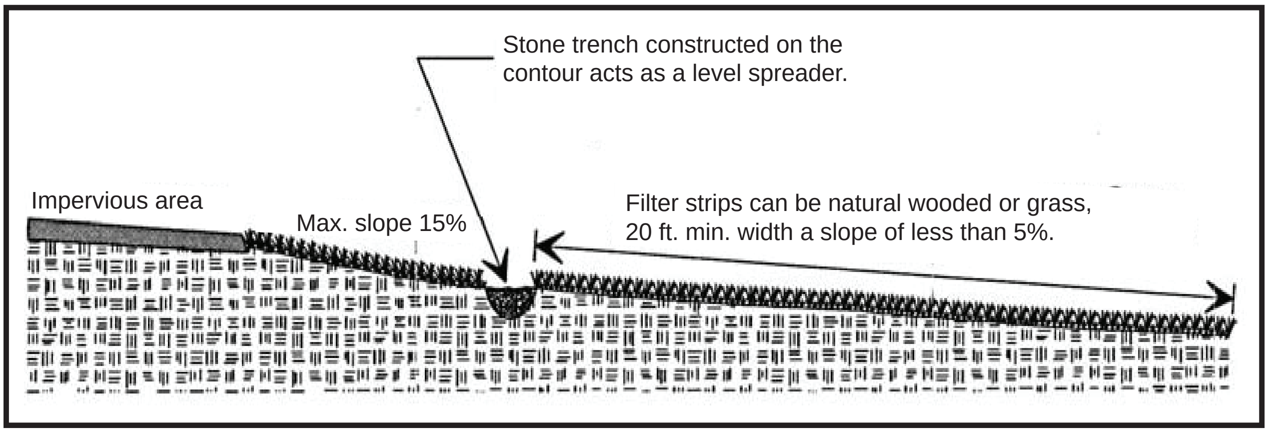


Figure 6.87 Vegetative Buffer Strip

Erosion Control

- Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete.
- Direct all overland flow to the vegetative buffer strip or the level spreading swale at low velocities.

Safety

- Store all construction materials and waste material well away from the vegetative buffer strip.
- Follow all local, state and federal guidelines in constructing utility trenches. If utility lines are buried beneath the vegetative buffer strip, do not perform final grading until all trench settlement has taken place. Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Provide temporary fencing and warning signs until vegetation is established.

Construction Verification

Check the finished grades and configuration of all earthwork, level spreaders and diversions.

Maintenance, Inspection and Removal

- Check for eroded channels in the vegetative buffer strip after every storm event. Fix eroded areas and reseed, mulch and fertilize the affected area. Modify the Storm Water Pollution Prevention Plan to prevent further issues.
- Apply fertilizer in accordance with soil test recommendations and always consider application timing and rates that will protect water quality – i.e. do not apply more than is necessary and do not apply when rain will likely carry fertilizer off to the stream system. Excessive fertilizer can cause a change in pH that allows heavy metals and other toxic compounds to become mobile and available for uptake by aquatic plants and animals. The change in pH can also prohibit nutrient uptake by the targeted vegetation.
- Remove sediment deposits accumulating in the vegetative buffer. This should be done very carefully to avoid damage to the vegetation.
- Protect new plantings from livestock or wildlife.
- Mow grass strips to a height of 6- to 12-inches two to three times a year to suppress weeds and woody vegetation unless natural, woody vegetation is indicated on the plan.
- Repair foot paths and traffic ruts.
- Remove the temporary vegetative bufferstrip and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a design professional if any of the following occur:

- Variations in topography on-site indicate vegetative buffer strip will not function as intended.
- Design specifications for fill, rock, sod, seed, mulch or fertilizer cannot be met; substitution may be required. Unapproved substitutions could lead to the vegetative buffer strip not operating as designed after construction activities have been completed.
- Naturally vegetated areas intended for use as buffer strips have been damaged or inadvertently reduced in width.

Common Problems and Solutions

Problem	Solution
Inadequate vegetation causing erosion of vegetative buffer strip due to too great a length of overland flow, too great a slope or high flow rates due to a drainage area greater than 5 acres.	Repair erosion damage and reevaluate erosion protection measures.
Inadequate vegetation causing erosion of vegetative buffer strip due to malfunctioning irrigation or lack of proper watering to establish the vegetation.	Repair erosion damage and possible irrigation issues, provide sufficient water for plant establishment and reevaluate erosion protection measures.
Settlement of soil in utility trenches or settlement of fill creates ponding within the vegetative buffer strip.	Fill low areas and regrade to provide proper drainage.
Uneven slope or debris clogging the trench at top of vegetative buffer strip creates a diversion of flow around vegetative buffer strip.	Remove debris and regrade as needed to provide proper drainage.
Sediment and debris clogging upper end of vegetative buffer strip creates a reduction in flow across vegetative buffer strip.	Replace clogged portion of vegetative buffer strip.

Dewatering

Figure 6.88 Use of a dewatering bag where storm water is pumped into a geotextile bag. The sediment stays in the bag while the storm water is allowed to flow out through the small voids in the material.   Source: ACF Environmental Inc.

Practice Description

Dewatering is a commonly required practice occurrence after a storm event on a construction site. Dewatering is performed in excavated work areas such as utility trenches and footings to clear the area of storm water so work can be performed. It may also be required on sediment traps or basins that are designed to pond water to make storage room for additional storm water during the next rain event. It is also performed in excavated work areas such as utility trenches and footings to clear the area of storm water so work can be performed.

Dewatering can be performed with a suction pump or other device such as a skimmer. Dewatering of storm water from sediment traps or basins must be limited to removing only the top or surface water containing the least amount of sediment. When dewatering with a pump, the water should be pumped into a device such as a geotextile bag or temporary sediment trap to remove or settle the sediment and allow the treated or clearer storm water to be discharged.

Recommended Minimum Requirements

It is best if the stored storm water in the trap or basin has been allowed to sit a minimum of 24 hours after the storm event. Depending on the types of soils and high clay content, additional settling time may be necessary before dewatering the trap or basin. If the intake must be close to the bottom of the excavated area it should be protected with a cloth or geotextile sock to reduce the amount of sediment particles exiting through the hose.

Water must be withdrawn from the top of the basin or treated through a geotextile bag or other treatment system before the storm water is allowed to leave the site.

Maintenance, Inspection and Removal

- Maintain the pump in proper operating condition and make sure the pump does not cause pollution to the surrounding area from fuels, oils, greases or other operating fluids. Monitor the dewatering and discontinue when the discharge begins to contain heavier sediment loads.
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Make sure the sediment has a proper settling time and sediment laden water is not discharging from the construction site.
- Make sure the geotextile bag (if used) is the proper size for the amount and velocity of flow going into the bag.
- Make sure the geotextile bag is located where it can be accessed for removal. The bag can be heavy, particularly when sediment is wet.
- It is also a good idea to have the dewatering bag placed so the discharged storm water can flow over a vegetated buffer strip or other area of vegetation, if possible.

Common Problems and Solutions

Problem	Solution
Pump loses suction – pump has lost its prime.	Reprime pump and begin dewatering activities.
Pump hose becomes clogged - the protective sock at the end of the hose has become saturated with sediment.	Clean or replace sock and keep the end off the bottom of the trap or basin and out of sediment laden water.
Erosion around the dewatering bag caused by locating the bag on an unstable surface.	Stop dewatering and move the bag to a stable (non-erodible) surface and continue the dewatering process.

Sediment Basin

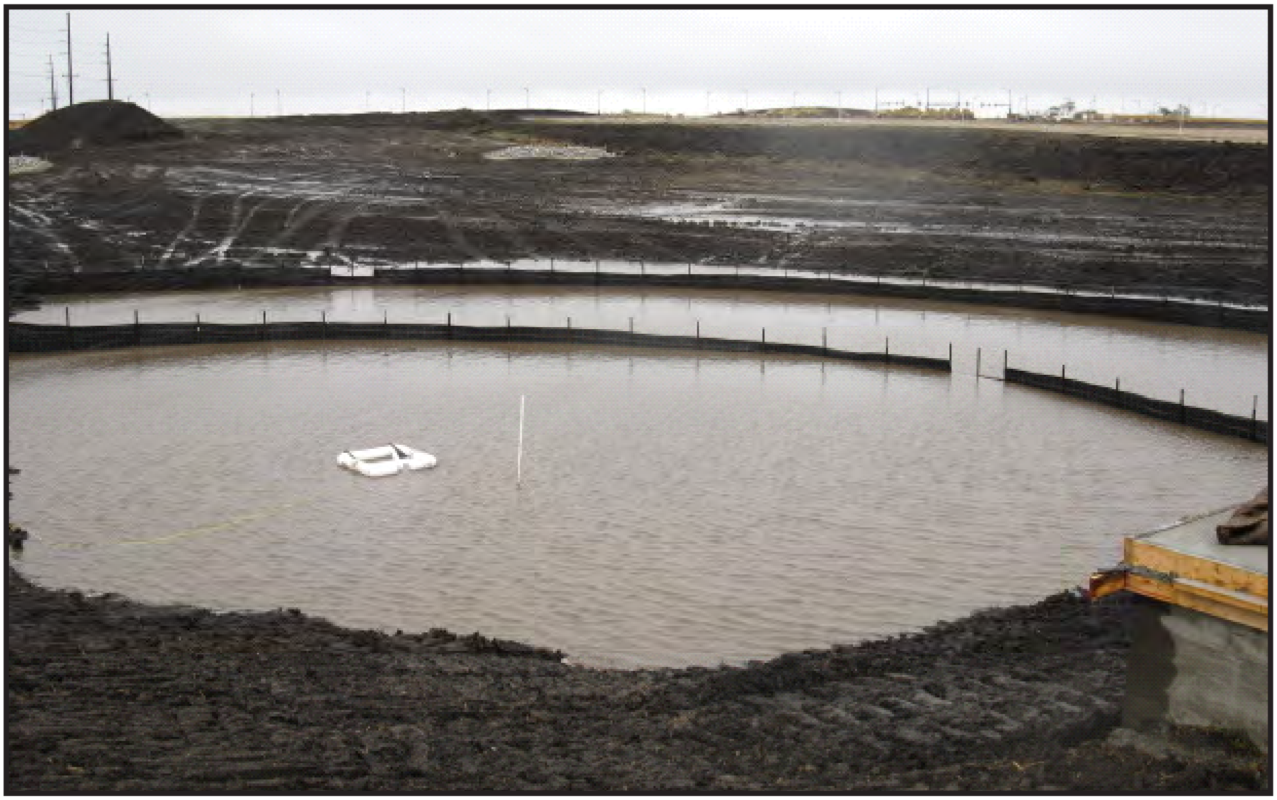


Figure 8.89 A sediment basin can be used to pretreat sediment-laden water before it discharges from the construction site.
Source: BFA Inc.

Practice Description

A sediment basin is a temporary pond constructed to contain sediment-laden storm water for an extended period of time prior to the storm water discharging from the basin. A sediment basin is temporary and should be removed or retrofitted prior to any final construction activities that would make these features a permanent detention or retention pond, after the entire contributing drainage area is stabilized.

This practice applies where other erosion control measures are insufficient to prevent off-site sedimentation. The purpose of a sediment basin is to detain sediment-laden runoff from disturbed areas in wet storage long enough for most of the sediment to settle out.

Recommended Minimum Requirements

Prior to the start of construction, sediment basins should be designed by a registered design professional. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process and anytime maintenance practices are required.

Build the sediment basin according to planned grades and dimensions.

Dam Height

10 feet or less.

Contributing Drainage Area

On project sites greater than 10 acres, contributing area is limited to 20 acres or less.

Structure Life

Limited to 10 years.

Detention

At least 24 hours or per local requirements.

Storage Volume

Minimum of 3,600 cubic feet per acre of contributing drainage area (pervious or impervious).

Trap Efficiency

The length to width ratio of the basin should be 2:1 or greater; 5:1 is optimal to capture fine sediments. Locate the inlet as far as possible upstream from the outlet.

Short Circuiting

Design the inflow to the pond as far away from the discharge point as possible. If not possible, design a baffle, weir or wall between the inflow and outflow to increase distance and travel time so there is maximum settling time prior to storm water discharge.

Embankment

- Top Width: At least 6 feet.
- Side Slopes: 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Settlement: Allow for at least 10 percent.
- Fill material: Stable moist soil compacted in lifts less than 8 inches.

Anti-seep Devices

Either of the following is recommended:

- Use at least two watertight anti-seep collars around the outlet conduit; collars should project 1- to 3-feet from the pipe.
- A sand diaphragm (see Glossary).

Risers

- Hold risers in place with an anchor or large foundation to keep them from becoming buoyant.
- Install appropriate inlet protection on the riser.
- Pipe size for the primary conduit should restrict discharge into the natural drainage area at a rate and volume of storm water that meets the local regulatory requirements and the design plan.

Emergency Spillway

- Constructthe spillway in undisturbed soil in a location that will not erode the dam.
- Cross Section: Trapezoidal-shaped with side slopes of 3:1 or flatter
- Control Section: Level, straight and at least 20 feet long. The spillway should have a minimum width of 10 feet.
- Stabilization: Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. Install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

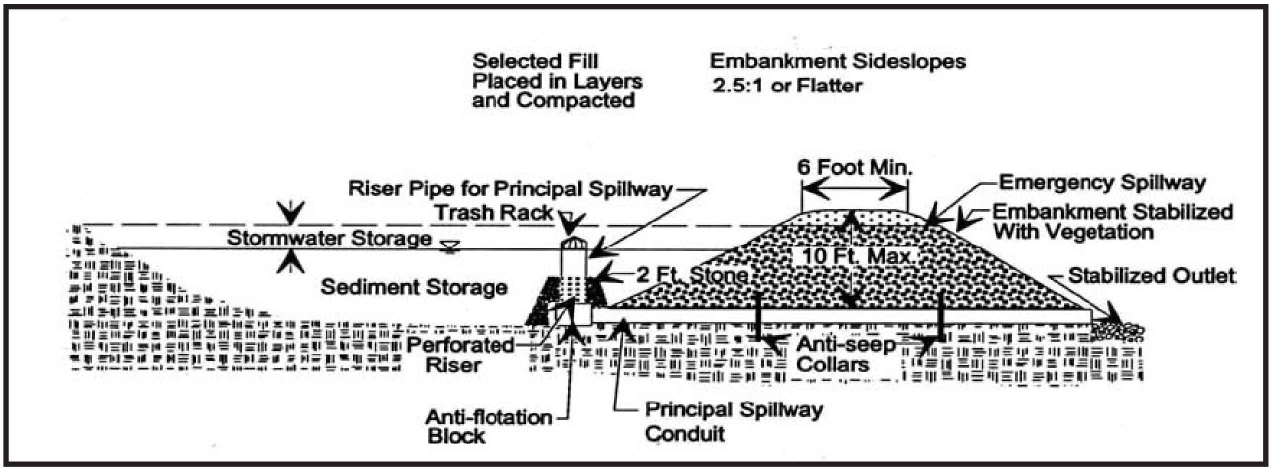


Figure 6.90 Typical Sediment Basin

Construction

Locate the sediment basin as close to the sediment source as possible, considering soil type, pool area, dam length, spillway conditions and proximity of sensitive habitats.

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements for impoundments. Clear, grub and strip the dam foundation, removing all woody vegetation, rocks and other objectionable material.
- Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Excavate the foundation (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Principal Spillway

- Construct a level sediment pool bottom to aid in sediment clean out. Situate the spillway barrel (pipe) and riser on a firm, even foundation. Prepare the pipe bedding.
- Place a 4-inch layer of moist, clayey, workable soil (not pervious material such as sand, gravel or silt) around the barrel, and compact with hand tampers to at least the density of the foundation soil. Don't raise the pipe from the foundation when compacting under the pipe haunches.

  Perforate the lower half of the riser with 1/2-inch diameter holes spaced 3 inches apart or use a manufactured perforated riser.
- Embed the riser at least 12 inches into concrete, which serves as an anti-flotation block. The weight of the concrete should balance the buoyant force acting on the riser.

$$\text{Buoyant Force} = \text{Volume of Riser} \times 62.4\ \text{lbs/ft}^3$$

- Surround the riser with 2- to 3-inch diameter clean stone to the height of the perforations on the riser. The stone footprint diameter should be 2 feet for every 1 foot of height.
- Place a domed inlet protector or steel trash rack around the riser inlet. The inlet protection should include overflow design. Trash rack openings should be no more than 4- to 6-inches square.
- At the pipe outlet, install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.

Embankment

- Scarify the foundation of the dam before placing fill.
- Use fill from predetermined borrow areas. It should be clean, stable soil free of roots, woody vegetation, rocks and other debris; and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.
- Compact the fill material in 6- to 8-inch continuous lifts over the length of the dam.
- Protect the spillway barrel with 2 feet of fill compacted with hand tampers before traversing over the pipe with equipment.

Emergency Spillway

- Construct and compact the dam to an elevation 10 percent above the design height to allow for settling.
- Place a reference stake indicating the sediment clean out elevation (50 percent of design elevation).
- Construct the spillway in undisturbed soil around one end of the embankment and locate it so that any flow will return to the receiving channel without damaging the embankment.

Stabilize the spillway as soon as grading is complete with vegetation, erosion control blankets or other erosion control stabilization practice; install riprap, TRM, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

Erosion Control

- Minimize the size of all disturbed areas. Vegetate and stabilize all disturbed areas as soon as construction is complete.
- Divert runoff from undisturbed areas away from the basin.
- Use temporary diversions to prevent surface water from running onto disturbed areas.
- Divert sediment-laden storm water runoff to the upper end of the sediment basin (as far from the outlet or spillway as possible) to improve trap effectiveness. A forebay may also be incorporated at the basin inlet to dissipate energy.
- Direct all runoff into the basin at a low velocity (channel slope less than one percent).
- Vegetate and stabilize all disturbed areas immediately after construction.

Safety

Because sediment basins that impound water are hazardous:

- Avoid steep slopes; slopes around the sediment basin should be 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Fence the area and post warning signs if trespassing is likely.
- Drain the basin between storm events.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Maintenance, Inspection and Removal

- Inspect the sediment basin weekly and after each storm event.
- Remove and properly dispose of sediment when it accumulates to one-half the design volume. Proper disposal of sediment may entail placement at a stock pile or other area up gradient of the pond. Spread it out to allow drying and then stabilize it.
- Check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Remove trash and other debris from the riser, emergency spillway and pool area.
- Clean or replace the gravel around the riser if the sediment pool does not drain properly.
- Remove the basin after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water (see Dewatering), removing the sediment to a designated disposal area, smoothing the material to blend with the surrounding area; and then stabilize. If this temporary sediment basin is to be converted to a permanent storm water control measure, or SCM, such as a detention, retention or infiltration basin, refer to your plans and specifications. Make sure the site is entirely stabilized before the permanent device becomes operational (no sediment-laden water should be entering the SCM.)
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Seepage is encountered during construction.	It may be necessary to install drains.
Variations in topography on-site indicate sediment basin will not function as intended.	Consult with registered design professional.
Design specifications for fill, pipe, seed variety or seeding dates cannot be met.	Substitutions may be required. Unapproved substitutions could lead to failure.
Piping failure along conduit caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair embankment using proper construction methods and materials.
Erosion of spillway or embankment slopes caused by inadequate vegetation or improper grading and sloping.	Repair using proper grades and slopes. Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.
Riser and barrel blocked with debris	Remove debris and install trash guard.

Problem	Solution
Overtopping of the principal and emergency spillway caused by undersized principal or spillway design.	Repair erosion damage and reevaluate spillway design.
Frequent operation of emergency spillway and increased erosion potential caused by lack of maintenance.	Clean the sediment out of the basin on a regular basis.
Frequent operation of emergency spillway and increased erosion potential caused by undersized principal spillway.	The sediment basin was designed with insufficient volume. Enlarge the basin or install additional sediment traps upstream in the watershed.
Slumping or settling of embankment caused by inadequate compaction or use of unsuitable soil.	Repair damage with suitable, well compacted material.
Slumping failure caused by steep slopes.	Flatten slopes.
Severe erosion below principal spillway caused by inadequate outlet protection.	Install adequate outlet protection.
Turbid water coming out of outfall pipe; small clay particles do not have sufficient time to settle out. The primary problem is that too much sediment is coming from above. Take needed steps to reduce the overloading of sediment to the basin.	Consult with the registered design professional to pursue additional features such as installation of a pre-sediment basin, addition of baffles or addition of particle curtains.

Do not apply water clarifying chemicals such as polymers to the final sediment basin. If the choice is made to use water clarifying chemicals earlier in the treatment process, see Chemical Application for Turbidity Reduction. Note any restrictions or controls required in federal, state or local regulations.

Chemical Application for Turbidity Reduction

Practice Description

Chemicals such as anionic polymers (polyacrylamide, or PAM) and formulated chitosan products can be mixed with on-site storm water to increase the settling rate of sediment particles. These water clarifying compounds, or water clarifying compounds, cause very small clay soil particles to bind together to form floccules (often referred to as flocs) that clump together and settle out. Small particles can otherwise take many days (if ever) to settle out of the collected storm water.

It is important to protect the receiving waters from aquatic toxicity. If a decision is made to use water clarifying compounds, it is vital they be formulated, selected and mixed properly into the collected storm water. Any material can be toxic if used incorrectly, whether it is naturally occurring or synthetic. Manufacturer's specifications should be followed, and responsible parties should be trained to administer the products properly.

Consideration should be given first to erosion control and then appropriate sediment catchments as the main treatment for turbidity and suspended solid particles. It is also recommended land disturbance be phased in a way to keep disturbance areas as small as possible, as a way to protect water quality and to meet storm water regulations (see Chapter 1.) This proposed staging and dispersement of smaller sediment catchments is compatible with today's placement of permanent storm water control measures.

Note: Large detention basins are no longer the sole preference for permanently managing storm water, because management has evolved to include dispersed practices as a way to meet storm water quality regulations. (see Post-Construction Section).

If that approach is not feasible or fails to produce successful results, the permittee may utilize water clarifying compounds specified by the design engineer with appropriate instruction and application training. If the decision is made to use water clarifying compounds:

- Use water clarifying compounds in conjunction with a best management practice that allows the flocs to settle out and maintain storm water control regularly to ensure the settled flocs are collected and removed from the system to prevent them from unintentionally entering nearby waterbodies.
- Determine if water clarifying compounds are best applied in conjunction with particle curtains, dispersion fields, baffles, a sand filtration system or other practice, and such system should be designed by a licensed engineer, with appropriate consideration of:
  - The nature of the receiving water.
  - System sizing.
  - Pond sizing.
  - Flow requirements.
  - Method of dosing.
  - Proper pH range and pH protection.
  - The system must be designed to capture sediment on-site.

- The operator must be properly trained to use the system and should have direct access to written specifications and operation procedures.
- Site-specific soil bench testing (e.g., jar testing) should be done in advance to determine proper application rates and methods per manufacturer's specifications. This will help to meet state and federal water quality standards for nephelometric turbidity units and to assure the chemical is performing to the best of its ability.
- The water clarifying compounds must be mixed into the water at a specified flow rate to ensure proper dispersion and ion exchange.
- Effluent should be monitored for residual chemical products or aquatic toxicity.
- Keep records for chemical use, effluent testing and corrective measures taken.
- Chemicals must be handled and stored according to applicable material safety data sheets.
- All construction land disturbance (state and local) permit requirements must be met.
- Local regulations may also govern the use of water clarifying compounds.
- Your local or state permitting authority may require prior review and approval of any use of chemicals to control erosion or turbidity, and if approved, include details in the storm water pollution prevention plan.
- Any product, including anionic water clarifying compounds, can be toxic to aquatic life if applied inappropriately.
- Use only products that have undergone whole product testing in an EPA approved laboratory using EPA protocol for acute and chronic toxicity.
- Do not use cationic "PAM", unformulated chitosan, alum or ferric iron compounds as they can be toxic to fish at very low levels. Such material binds to fish gills or depletes available oxygen, hindering oxygen uptake.
- Do not apply directly to or in close proximity to waterbodies.
- Do not use in areas with a shallow groundwater table or highly permeable soils.

Note: The terms flocculant and polymer are commonly used in the storm water industry. Technically, coagulants are often positively charged chemicals used to bind with negatively-charged particles to form flocs. Flocculants are settling aids that increase the rate of this binding process by bridging flocs into larger clumps. The important thing to remember is chemical additives bind to pollutants through negative and positive ion attractions, and in order to protect water quality, strict attention should be paid to proper selection and application.

Particle Curtains

Figure 6.91 Particle Curtains. Source: Florida Erosion and Sediment Control Designer and Reviewer Manual, June 2007

Practice Description

Particle curtains are a series of curtains made of jute and coconut fabrics attached to floats to be used in a sediment pond or similar treatment device. Its purpose is to collect fine particles, when used with a site-specific water clarifying compound such as a floc log. The floc log needs to be upstream of the particle curtain. This storm water control measure is intended to slow down the water flow through the basin so particles can fall out. It is not intended to be a stand-alone measure as it is not adequate sediment control by itself. Use this measure with sediment basins or traps.

- Secure the site-specific water clarifying compound far enough upstream to allow for appropriate mixing with the turbid water. Make sure the water can flow over and around the floc logs, adding mixing structures if needed to increase turbulence around the floc logs to facilitate proper mixing.
- Install the particle curtains in lines perpendicular to the flow across the sediment pond or waterway.
- The particle curtains will float.
- Inspect and repair or replace the particle curtains as require.

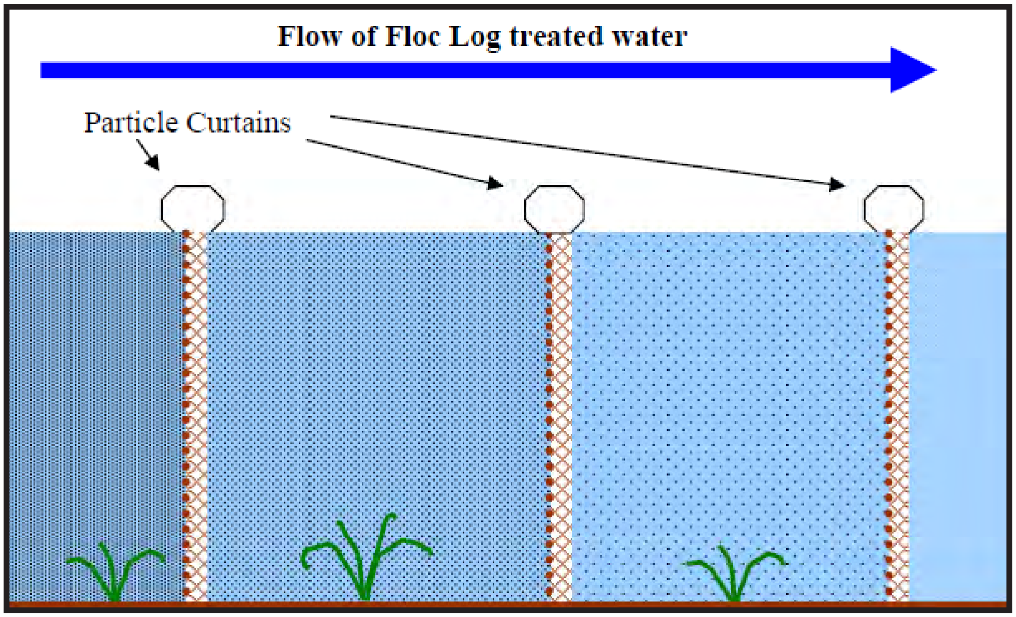


Figure 6.92 Source: *Polymer Enhanced Best Management Practice Application Guide*, March 2010

Maintenance, Inspection and Removal

- Inspect the device prior to use and make sure it is in proper working order. Repair, if necessary.
- Inspect the device periodically while it is in operation so it does not discharge sediment laden water from the construction site.
- Remove the device prior to the end of construction either when the sediment basin is removed or transformed into a permanent storm water control device.
- Remove the temporary particle curtains and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 - Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Anchoring devices (e.g, chains attached to weights) can be too short or too tight and therefore not allow curtain to rise and fall with water motions.
- Severe weather may dislodge the floating device and allow a turbid water release.
- Sediments allowed to drain from areas above the high water mark can overload the curtains.

Common Problems and Solutions

Problem	Solution
The curtain loses its shape.	It must be re-anchored. If it continues to break away from the anchors, more anchor points may be necessary.
If the curtain becomes submerged.	The anchor points must be readjusted to allow movement with water level.

Floc Logs

Practice Description

Floc logs are for use in concentrated flow areas for treating turbid storm water. Floc logs are chemically enhanced fabric “logs” used to introduce site-specific water clarifying compounds to turbid waters in such a manner to facilitate mixing and reaction between the compound and the suspended particles. The log will slowly dissolve over time and release the chemical into the flowing water. The compounds will react with suspended sediment causing the particles to bind together.

This storm water control measure is intended for particle collection only. It is not intended to be a stand-alone measure, as it is not adequate sediment control by itself. Use this measure with a sediment pond or similar treatment system.

Do not place floc logs directly into streams, tributaries or in direct paths to streams or other waters of the state. Do not allow runoff from floc logs to flow directly into streams or waters of the state.

Place the floc logs where the sediment-laden storm water will flow over them:

- In ditches that feed a sediment pond or similar treatment system.
- At the intake or outlet of a recirculation system.
- Near the aeration system.

Place logs in a series, one after another. The number of logs is determined by the flow rate of the water and the length of the mixing ditch is determined by the reaction time required for the polymer.

Checks can be placed along the ditch, forcing the water to flow over and around them, to increase turbulence and mixing with the floc logs. Cover the exposed soil in the ditch with jute matting and apply polymer powder to prevent erosion. With highly erosive soils, protection with geotextile or plastic sheeting may be necessary.

Inspect logs following each precipitation event and replace as needed. Use collected sediment higher up in the watershed as fill.

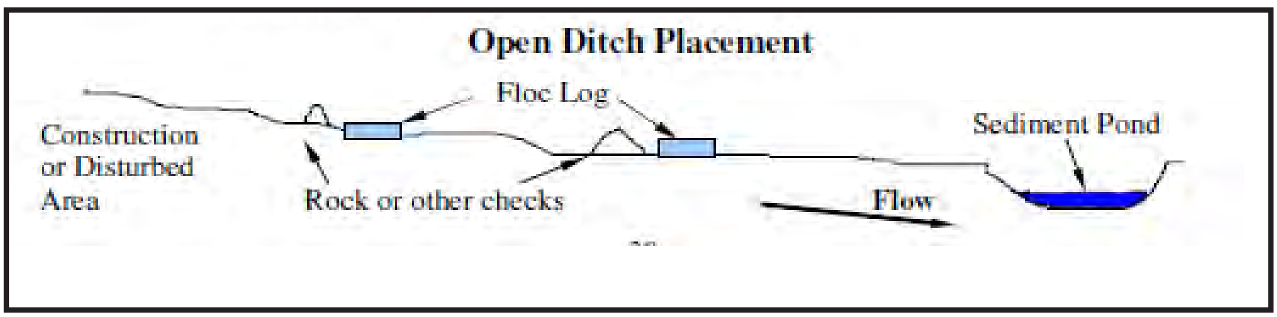


Figure 6.93 Open ditch placement.

Skimmers

Figure 6.94 A skimmer that provides dewatering from the top of the sediment basin. Source: *North Carolina Erosion and Sediment Control Planning and Design Manual.*

Practic Description

A skimmer is a dewatering device designed to remove water from sediment traps or basins. Dewatering the sediment storage structure, is a routine practice between storm events to accommodate additional storm water from the next event. A skimmer is a device that dewaters from the surface. Water at the surface should contain the least amount of sediment as particles settle to the bottom of the sediment storage structure.

Recommended Minimum Requirements

This device must be designed and engineered according to the size of the basin or trap they are dewatering. Therefore, stop dewatering activity when the device begins discharging sediment laden water.

Do not discharge sediment laden water from the construction site. Allow the storm water to sit in the trap or basin for an acceptable time prior to any dewatering activities. The acceptable time allowed for settlement will vary according to the size and type of sediment particles found within the sediment laden water.

Do not attempt to use a skimmer without the use of a baffle design (see Baffles). Part of the skimmer design includes not only the sizing of the skimmer itself, but an evaluation of the exact orifice size. These sizing decisions should be completed by the design engineer and incorporated into the storm water pollution prevention plan.

Do not apply water clarifying chemicals such as polymers to the final sediment basin. If the choice is made to use water clarifying chemicals earlier in the treatment process, refer to Chemical Application for Turbidity Reduction. Note any restrictions or controls required in federal, state or local regulations.

Construction

Follow manufacturers' recommendations for design and sizing of the device.

Troubleshooting

Device discharges sediment laden storm water; caused by lack of baffles or improperly notched baffles that cause sediment-laden strom water to enter the final section of the basin:

- Stop discharging and allow the pond to be still for at least 24-hours to settle sediments before dewatering.
- Stop the flow of dewatering when the device lowers into heavier sediment laden water in the trap or basin.
- Allow the storm water to sit for a longer period so the sediment settles to the bottom of the trap or basin before dewatering.
- Device clogs. Keep the device clean of dirt, sediment and leaves, twigs or other debris so it remains in good working order.
- Maintain the device in proper operating order per manufacturer's recommendations and do not allow the device to clog or fill with sediment.

Maintenance, Inspection and Removal

- Inspect the device prior to use and make sure it is in proper working order. Clean if necessary.
- Inspect the device periodically while it is in operation so it does not discharge sediment laden water from the construction site.
- Remove the device prior to the end of construction either when the sediment basin is removed or transformed into a permanent storm water control device.
- Remove the skimmers and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 - Missouri Permit Requirements) for termination of permit coverage.

Baffles

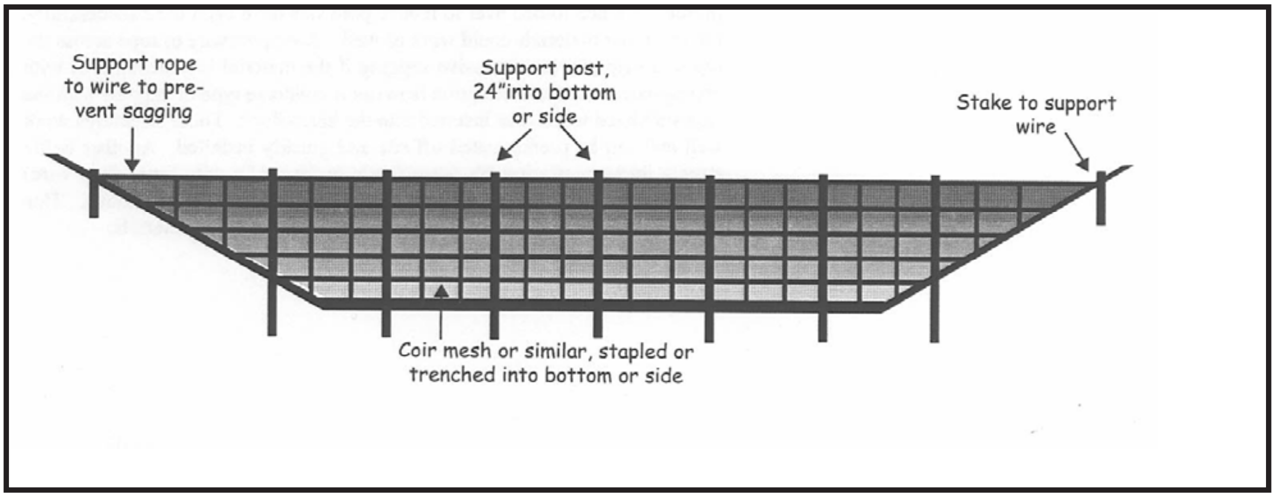


Figure 6.95 Cross-section of a porous baffle in a sediment basin. Note there is no weir because the water flows through the baffle material. Source: *North Carolina Erosion and Sediment Control Planning and Design Manual*

Practice Description

- Baffles are porous barriers installed inside a temporary skimmer or sediment basin to reduce the velocity and turbulence of the water flowing through the measure, and facilitate the settling of sediment from the water before discharge.
- Baffles improve the rate of sediment retention by distributing the flow and reducing turbulence. This process can improve sediment retention and allow the capture of soil particles 50 percent smaller than those that can be captured without baffles.
- Use this practice in any temporary sediment basin.
- Porous baffles effectively spread the flow over the entire width of a sediment basin or trap. Water flows through the baffle material, but is slowed sufficiently to back up the flow, causing it to spread across the entire width of the baffle (Figure 5.77). Spreading the flow in this manner uses the full cross section of the basin, which in turns reduces flow rates or velocity as much as possible. In addition, the turbulence is also greatly reduced. The combination practice increases sediment deposition and retention and also decreases the particle size of sediment captured. The storm water flows into the first section where the larger contaminants settle out before spilling over to additional sections. As a result, the first section should be easily accessible for maintenance.
- The installation can be similar to a sediment fence. Materials such as jute backed by coir erosion blanket, coir mesh, or tree protection fence folded over to reduce pore size have been used successfully. Other similar materials could work as well. A support wire or rope across the top will help prevent excessive sagging if the material is attached to it with zip ties. Another option is to use a sawhorse type of support with the legs stabilized with rebar inserted into the basin floor. These structures work well and can be prefabricated off-site and quickly installed. Success has also been demonstrated by placing silt fence fabric in front of the wire fence backing which has alternating squares.

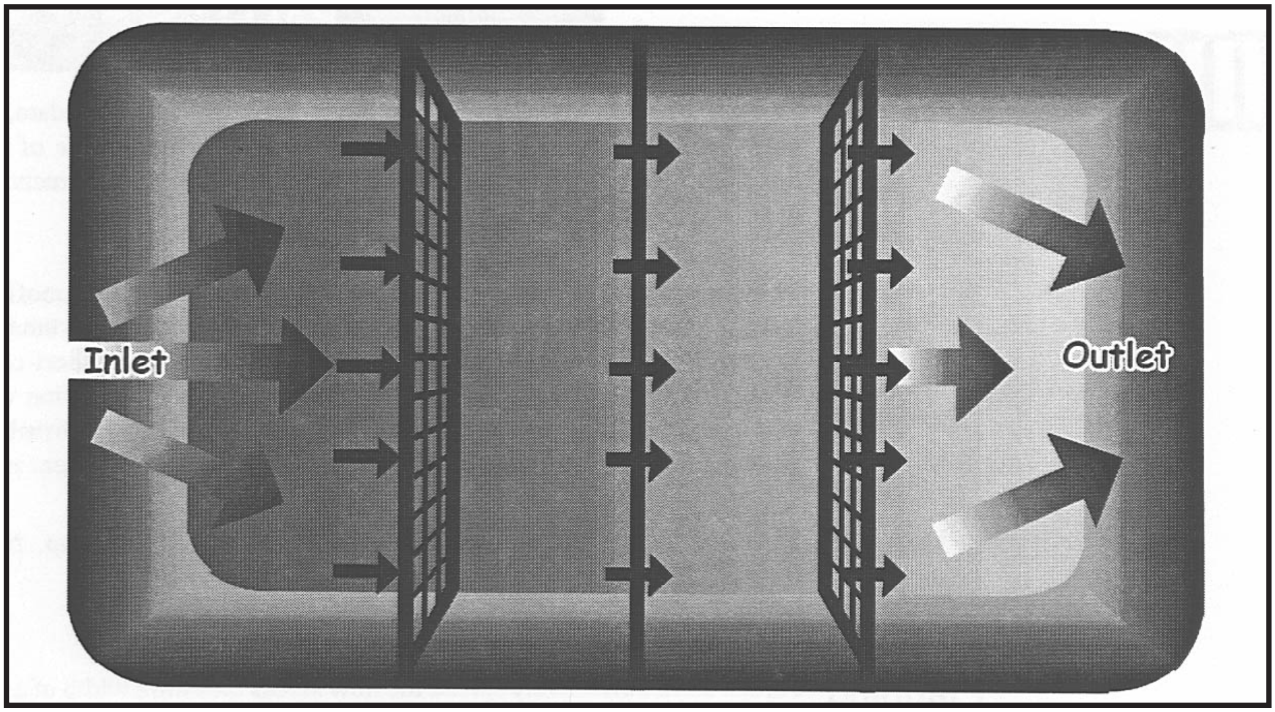


Figure 6.96 Porous baffle in a sediment basin. Source: *North Carolina Erosion and Sediment Control Planning and Design Manual*

- Newer baffle technology includes filtration baskets to catch the floating vegetation and litter at the top of the box, while the sediment is captured in the bottom of the box. This separation of organic matter from the water and sediment, provides a reduction in the nutrients and sediments present in the storm water.
- Remove the baffles and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 - Missouri Permit Requirements) for termination of permit coverage.

Dispersion Fields

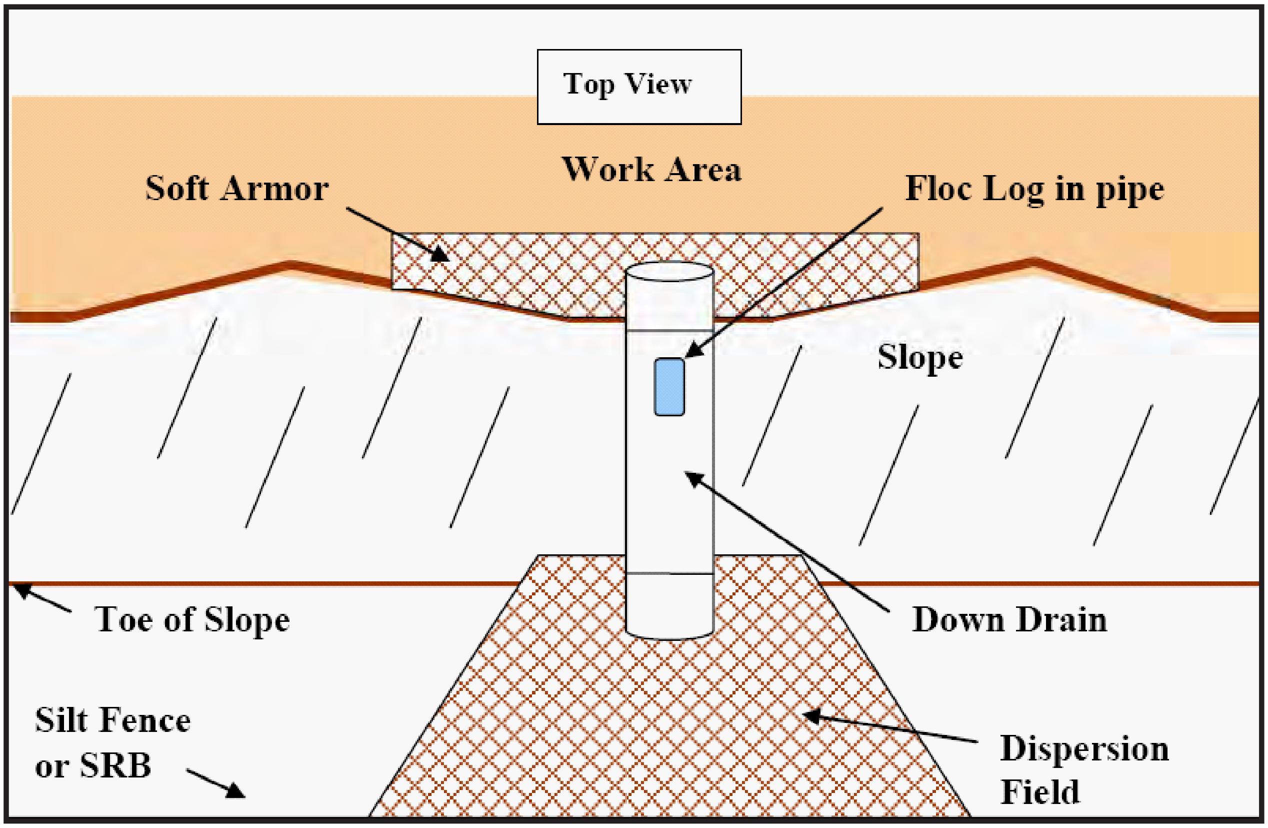


Figure 6.97 Source: *Florida Erosion and Sediment Control Designer and Reviewer Manua*l, June 2007.

Practice Description

Dispersion fields are to be used in conjunction with other best management practices, as it does not provide adequate sediment control by itself. The dispersion field should be covered in jute matting and applied with the site-specific water clarifying compound powder, to provide a surface for the particles to adhere to and help in final clarification of the storm water. A dispersion field is created to allow treated storm water to spread out and slow its velocity. Other best management practices must be used in conjunction, (e.g., floc logs, silt fences, down drains, soft armor matting) to further reduce velocity. The size of the field is dependant on the amount and velocity of storm water expected to enter. With highly erosive soils, protection with geotextile or plastic sheeting may be necessary.

Limitations

High flow velocities will occur at the discharge end of the slope drain. Unless there is a great distance between the slope drain discharge end and the silt fence, and a sediment basin or pond is created, the silt fence barrier may be destroyed if the inflow values are greater than outflow.

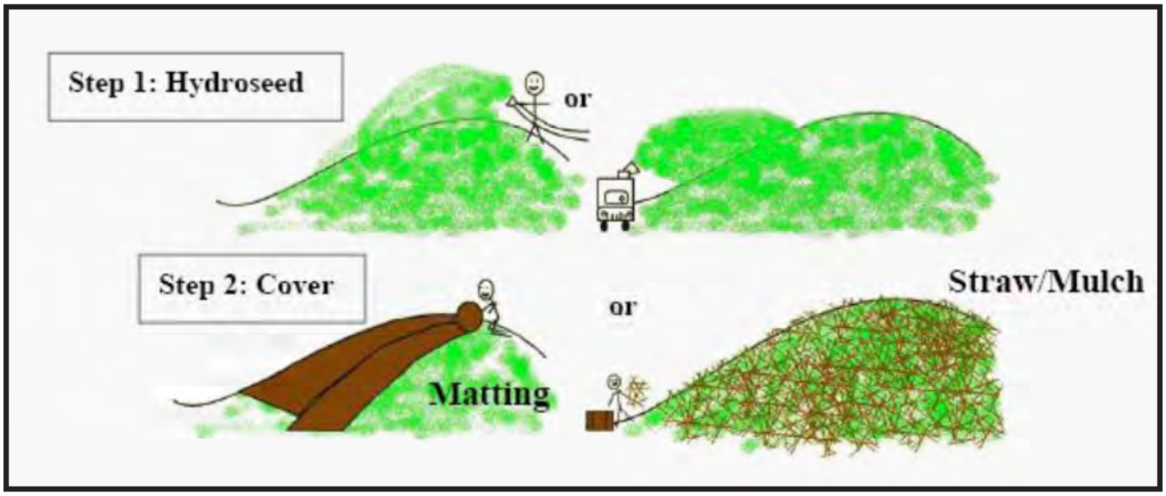


Figure 6.98 Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007.

Inspection And Maintenance

Inspect routinely. Repair coverage and re-apply media as needed to maintain maximum protection against erosion. If failure of media occurs routinely, consider another type or size of protective media.

Dispersion Fields

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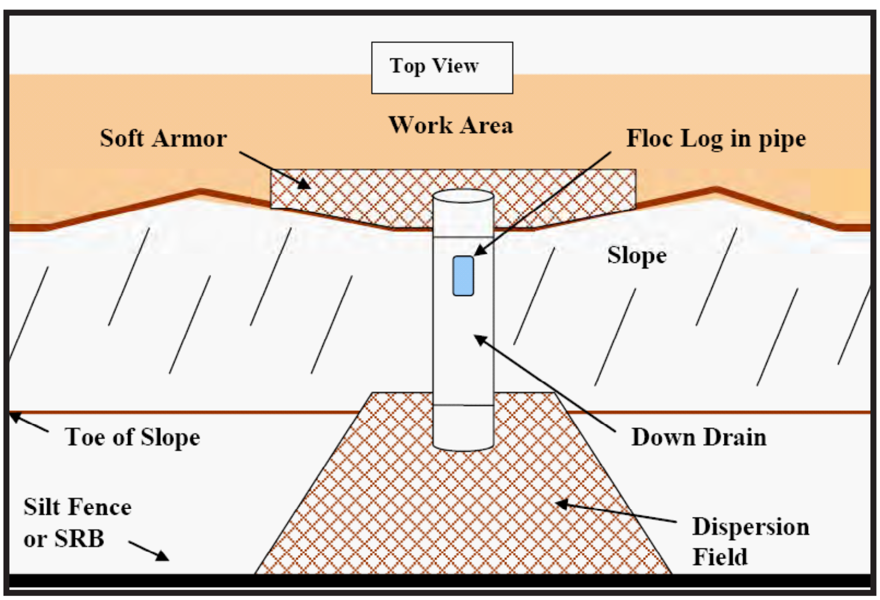


Figure 6.99 Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007.

Sand Media Particulate Filter

Practice Description

In a sand media particulate filter, water is treated by passing it through canisters filled with sand media. Sometimes, water clarifying compounds are added to flowing storm water before it enters the filter. Generally, sand filters are used to provide a final level of treatment. They are often used as a secondary or higher level of treatment after a significant amount of sediment and other pollutants have been removed.

Figure 6.100 Sand Media Particulate Filtration System Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007.

Recommended Minimum Requirements

Water clarifying compounds can be used to aid in settling the smaller soil particles when there is a high concentration of smaller clay particles. This can shorten the time necessary for settling out sediment particles from when the storm water flow enters the sediment storage structure and when it discharges. Water clarifying compounds can be toxic if used incorrectly or allowed to leave the construction site at all, but especially if caused to do so prior to binding with soil particles. Plans and manufacturer specifications and recommendations should be referred to by the site superintendent and field personnel throughout the construction process.

Do not over apply or misuse water clarifying compounds. Follow land disturbance permit requirements, check local ordinances for any restrictions that may apply and do not allow any form of the chemicals to discharge from the site or cause a violation of federal or state water quality standards.

Construction

- Follow manufacturers recommendations for the use of water clarifying compoundss and sand filtration systems. Significant site assessment (including soil testing) is required to determine the exact location of polymer application, the amount of material to use and other key elements for success.
- Construction of the treatment system using water clarifying compounds can be “active” or “passive”. An active treatment system is a designed system that incorporates pumps and sand filters while a passive treatment system is designed to rely on settling ponds, check dams, filter dikes, inlet floc socks, etc.

Maintenance, Inspections and Removal

- Inspect coagulant applicator and sand filtration treatment systems on a weekly basis and after rain events. Maintain the systems as required.
- Remove the system when construction is complete and the stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Flocculating water clarifying compounds are soil specific and soil tests must be done to determine the most effective application. Other coagulants are more general and will work on a wide range of soils. Most coagulants are pH and temperature sensitive. Follow all manufacturer’s specifications and recommendations.
- Do not over apply or misuse water clarifying compounds.

Common Problems and Solutions

Problem	Solution
Despite use of water clarifying compounds, fine clays and colloids remain in suspension, caused by the wrong type of water clarifying compounds. used for the soils on-site.	Take additional soil samples and re-evaluate the appropriate type of product to use.
Despite use of water clarifying compounds, fine clays and colloids remain in suspension, because there was inadequate mixing time to dissolve the water clarifying compounds into the storm water.	Identify location further upstream from basin to introduce the water clarifying compound or identify areas with greater turbulence that would improve mixing.
Over application and premature purging of the compounds, caused by allowing the water clarifying compounds applicator for a passive treatment system to sit in standing water.	Locate applicator in ditch checks or in pipe outfalls in such a way to keep the applicator out of ponding water.

SECTION 5: PERMANENT STORMWATER RUNOFF MANAGEMENT

This section of the book highlights important considerations of environmental design in the site plan and offers general guidance for permanent stormwater control measures, referred to here as SCMs. See Chapter 2 for more information about water quality impacts and hydrology considerations. See Chapter 3 for more information about interpreting stormwater features in the site development plan.

SCMs are considered permanent and are designed to control stormwater discharges for both water quantity and water quality, after the site has been completely built. These devices may be constructed and installed during the construction phase of the project, but usually are not operated until project construction is complete and the site is stabilized.

General Contractor and Site Superintendent Responsibilities

Many communities are now required to regulate post-construction practices for water quality, therefore city or county regulations may apply in addition to state and federal regulations (See Chapter 1 for information about state regulations, federal regulations and permit requirements.) In order to avoid costly corrections and project delays, it will be important for the general contractor and site superintendent to:

- Understand local water quality requirements. Many communities are upgrading stormwater ordinances and codes, because they are now required to enforce development standards to meet water quality goals. As a result, requirements may include capturing and treating small storm runoff at the site. This makes it necessary to employ green infrastructure concepts and low impact development practices, in particular environmental site designs that include:
  - Features such as stream buffers, less impervious surface (narrower streets, etc.), streetscapes, connected green spaces, parking lot controls and pocket parks.
  - Strategically placed practices such as rain gardens, bioswales, stormwater wetlands, infiltration trenches, perimeter sand filters and planter boxes.
  - Similar practices to collect and treat small storm runoff.
- To avoid costly repairs, avoid damage to designated SCM locations during construction. Become aware of all planned SCMs designed for permanent function and identify where they are to be located. Contemporary designs can include numerous on-site SCMs throughout the project site. The ultimate placement and combined functions of SCMs, as well as their connected paths, need to be protected from soil compaction and other disturbances. Such protection will eliminate the need for costly repairs and will protect against failure of the SCM.

- Coordinate long-term operations with landowners. Local regulations for permanent stormwater control measures may require a formal transfer of operation and maintenance responsibility from developer to builder or buyer.
- Notify local governments about permanent practices where regulated. The site superintendent or general contractor should inform the local governing agency about the final location of all SCMs as well as who is in charge of the operation and maintenance of each control device. Check the local ordinance for requirements.

Design Considerations When Selecting Vegetated Practices

Many contemporary SCM devices work with vegetation to increase infiltration. Vegetation will work most effectively when a diverse mix of grasses, forbs, shrubs and trees are designed together. When choosing the vegetative material, incorporate plants with diverse root structures below ground to increase the potential for water uptake by the plants. This will also help to recharge groundwater resources. Also, grasses will provide more root structure and deeper root penetration if the plants are allowed to grow and are not mowed close to the ground. Native or adapted warm season grasses provide greater root structure (up to 15 feet) when they are not mowed, whereas mowed turf grasses only provide about 1- to 2-inch deep root structures. As a general rule, trees and shrubs provide greater root structure systems than grasses do.

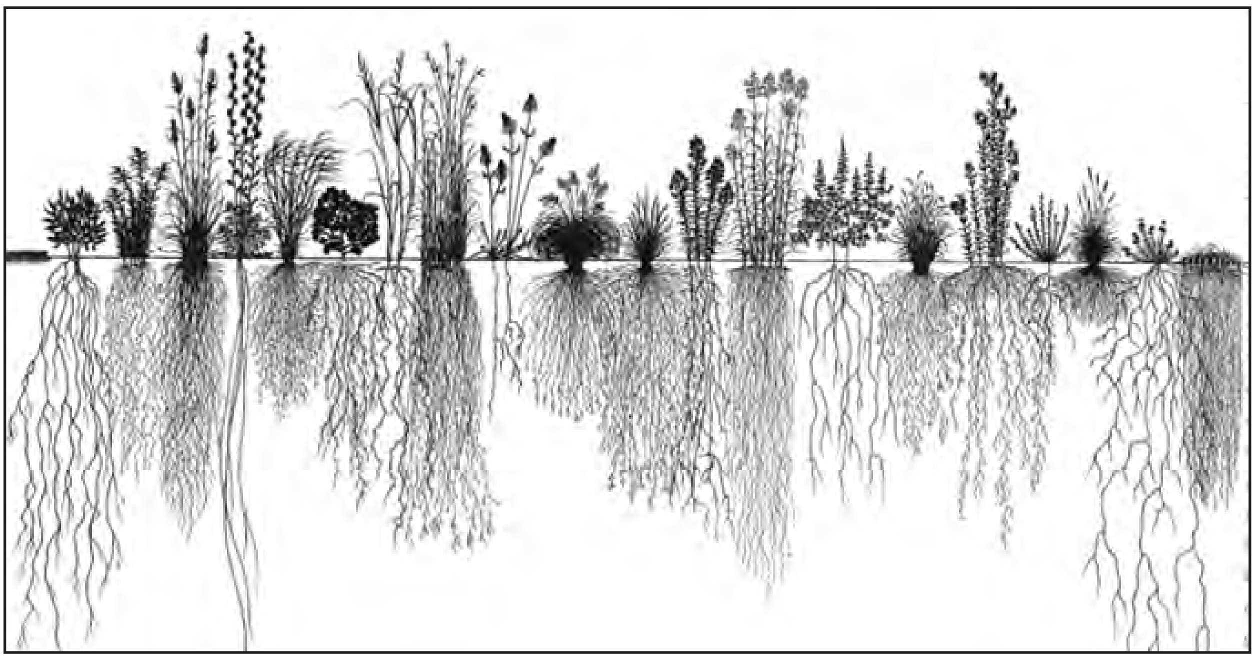


Figure 6.101 Source: *Native Plant Guide for Streams and Stormwater Facilities in Northeastern Illinois* Prepared by USDA-NRCS Chicago Metro Urban and Community Assistance Office in Cooperation with EPA Region 5, U.S. Fish and Wildlife Service, Chicago Field Office and U.S. Army Corps of Engineers, Chicago District, December 1997 (Revised May 2004).

Coordinating Long-Term Operation, Maintenance and Inspection

Long-term operation, maintenance and inspection needs, along with any safety concerns, should be communicated to the affected landowners, homeowners' association and other parties responsible for permanent oversight of the SCMs. Present and future landowners should be made aware of the potential consequences of changing vegetation types, poor maintenance practices or other actions that could cause a practice to function poorly or fail. A long-term education program should be implemented to ensure that multi-generational land owners understand the importance of maintaining practices. Without knowledge of their intended purposes, there is possibility new owners will disable functional features.

Preparing the Operation, Maintenance and Inspection Manual

Each stormwater control measure should have specific operation, maintenance and inspection information written in an operations, maintenance and inspection manual. The manual should be prepared by the design professional, and the entity responsible for operations, maintenance and inspection of each device should be identified. After construction is complete and all SCM devices are operational, the responsibility for operations, maintenance and inspection should be turned over to the proper entity, and the individuals should be provided adequate training for operations, maintenance and inspection.

Additional References and Resources

Refer to the design specifications used in your area for proper design, installation and maintenance. The *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management 2011* will provide additional information about these practices as well as non-structural strategies. See Appendix C and Appendix D for additional references and resources about environmental site design and state-of-the-practice permanent stormwater control measures.

Selecting Permanent Stormwater Control Measures

The current goal of stormwater management is to provide effective control over water quality, channel protection, recharge, overbank floods and extreme storms. Historically, the primary goal of urban stormwater management was to control the quantity peak flow rate for the purpose of flood protection.

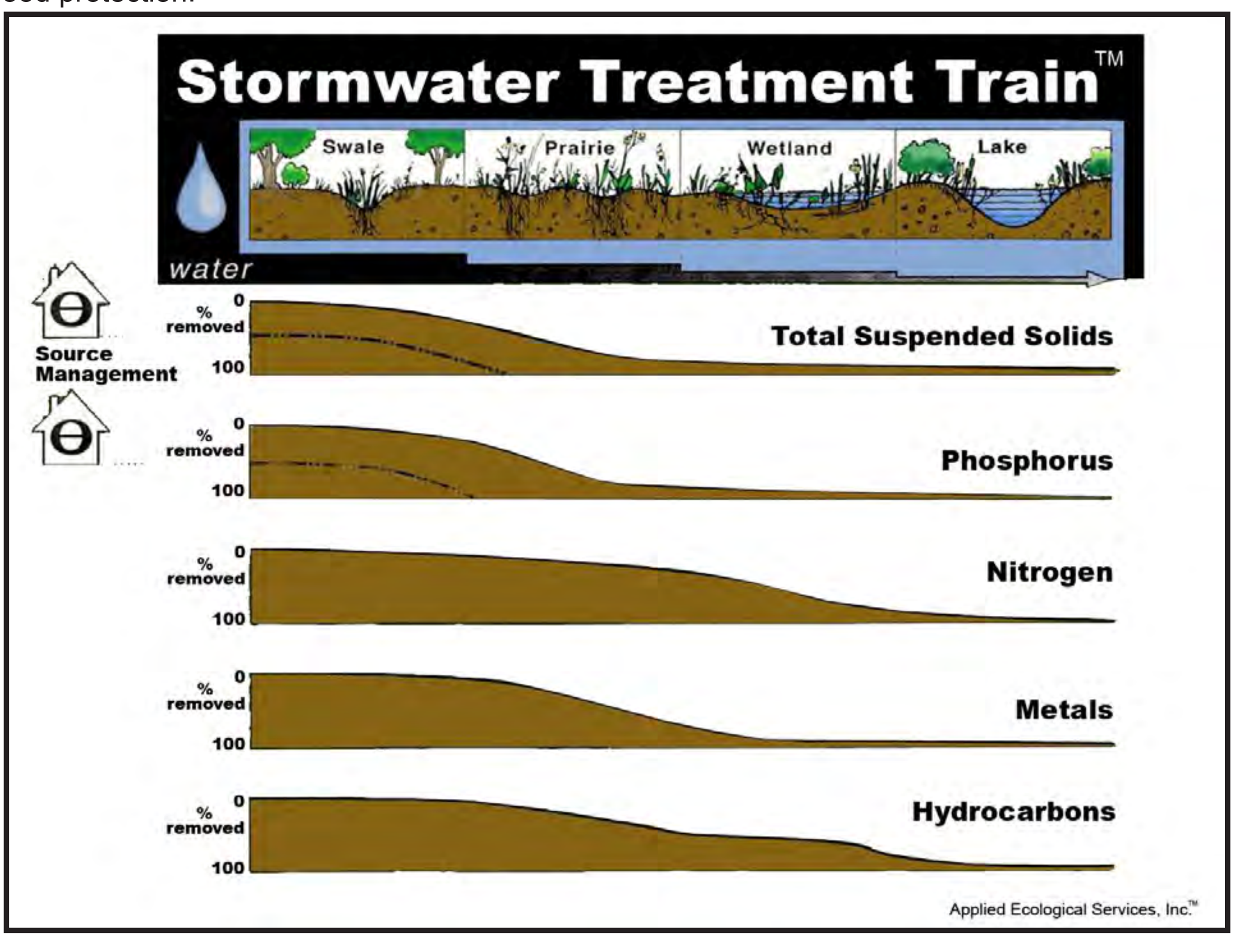


Figure 6:102 Stormwater Treatment Train printed with permission by Applied Ecological Services. See www.appliedeco.com for more STT information and project examples.

To meet current water quality goals, stormwater management practices should be selected with consideration of the overall site design. See Chapter 3 - Interpreting Stormwater Features in the Site Development Plan. Specifically, the design engineer should consider performance that combines pollution removal with water quantity control.

Pollutant Removal Mechanisms for Water Quality Control

Screening/Filtration

The capture of solid pollutants through screens or filters that use a media such as sand. Effective for removal of suspended solids.

Infiltration/Ground Water Recharge

A technique to discharge stormwater runoff to groundwater. Effective when runoff volume controls are required, pollutants can be filtered and surface water temperatures can be controlled.

Settling

Deposition of solids. Typically a minimum of 12 hours of detention is needed to effectively settle solids in stormwater ponds and stormwater wetlands.

Biological Uptake

Vegetative and microbial uptake of nutrients through biofiltration or stormwater wetlands.

Temperature Control

Techniques to reduce the heating effects when runoff flows across hot pavements.

Soil Adsorption

The physical attachment of a particle, usually nutrients and heavy metals, to the soil. See Table 6.17 for examples of practices that provide water pollution control.

Table 6.17 Primary and Secondary Pollutant Removal Mechanisms
Source: Minnesota Stormwater Control Manual

Best Management Practices Group	Pollutant Removal Mechanisms									
	Water Quality					Water Quality				
	Screening Filtration	Infiltration/ Recharge	Settling	Biological Uptake	Temperature Control	Soil Adsorption	Volume Control	Rate Control	Velocity Control	Evapotranspiration
Pollution Prevention	Not applicable - pollutants not exposed to stormwater									
Better Site Design/Low Impact Development	1	2	2	2	2	2	1	2	2	2
Runoff Volume Minimization		2			2		1	2		
Temporary Construction Sediment Control			1					1	2	
Bioretention	1	2	2	2	2	2	2	2		2
Filtration	1	2		2		2		2		2
Infiltration	2	1		2	1	2	2	2		
Stormwater Ponds		2	1	2				1	1	2
Stormwater Wetlands	2	2	1	1		2		1	1	2
Supplemental Treatment	Each supplemental and proprietary device should be carefully studied to learn the primary and secondary pollutant removal functions.									
1 = Primary Pollutant Removal 2 = Secondary Pollutant Removal Mechanism										

Water Quantity Control Mechanisms

Volume Control

Methods to limit the net increase in stormwater runoff volume caused by the creation of new impervious surfaces. Most common techniques include best site designs that offer limitation or disconnection of new surface areas, infiltration, evapotranspiration and re-use by vegetation.

Rate Control

Detention of stormwater runoff to slow the discharge of runoff to surface waters to rates comparable with pre-development conditions. Effective for peak rate control, but can significantly increase the time period of the peak flows.

Velocity Control

Similar to rate control; intentional restriction of stormwater runoff such that velocity of discharged runoff through downstream channels does not cause channel erosion.

Evapotranspiration

Specific volume control technique that uses evaporation from water surfaces or transpiration by vegetation.

See references listed in Appendix B for details about integrated stormwater management, SCM selections, specific SCM design schematics and the unified sizing approach. For example, the *Minnesota Stormwater Manual* provides detailed SCM calculations and designs, the *Low Impact Development Manual for Michigan* provides a summary of calculations and methodology, and the SUSTAIN model by EPA provides step-by-step site design and SCM selection exercises.

ROOFTOP RUNOFF CONTROLS
Rain Gardens

Figure 6.103: Maplewood, Minnesota Rain Garden. Source: University of Wisconsin-Extension and the Wisconsin Department of Natural Resources.

Practice Description

As one form of bioretention, a rain garden is designed to collect stormwater runoff from small areas. (See Bioretention System.) A rain garden is an attractive, landscaped area built in a natural or constructed depression and designed to capture and filter stormwater runoff as a natural system would. It is usually planted with perennial native or adaptive plants selected to tolerate periods of inundation and drought, although typically designed to drain in less than a day. Use rain gardens catch runoff from impervious surfaces such as rooftops, small parking lots, driveways and similar surfaces. They can be constructed in residential, commercial, parks or neighborhood areas or inside traffic roundabouts (See Figure 6.103).

Rain gardens can be constructed near the source of runoff to slow the stormwater, prevent erosion and filter pollutants before draining to local waterways. When used in combination with other rain gardens or practices, these gardens can help achieve desirable drainage rates, velocity reduction and groundwater recharge – specifically by capturing Rainfall from a small storm, or water quality storm (approximately a one-inch event) while diverting the larger storm runoff to the storm drain system. Rain gardens provide habitat and food for wildlife and enhance the aesthetics of an individual yard or a community.

Rain gardens are applicable across the Midwest, including cold climate or karst areas with minor design adjustments. They can be used individually to improve stormwater quality and reduce peak runoff rates for small areas such as rooftop drainage areas, or they can be used in multiples across a larger area. Rain gardens, as long as they are lined properly, can also be used to treat stormwater hot spots where pollution in runoff is higher than typical – gas station parking lots for example.

Figure 6:104 Rain garden in roundabout designed to capture/infiltrate stormwater, Milwaukee, WI. Source: Bob Newport, EPA Region 5

Recommended Minimum Requirements

Rain gardens should be designed by a qualified professional when they are to be built as part of a comprehensive stormwater management system. The site superintendent and field personnel should refer to plans and specifications throughout the construction process. If an individual homeowner wishes to install a rain garden, they should be able to install one by following simple guidelines. A great resource is *Rain Gardens: A How-To Manual for Homeowners* by Wisconsin Extension (see References).

Siting and Design Considerations

Consideration should be given to location of the runoff source, water quality goals, drainage volume target, slope, soil type, groundwater recharge goals, costs and performance limitations.

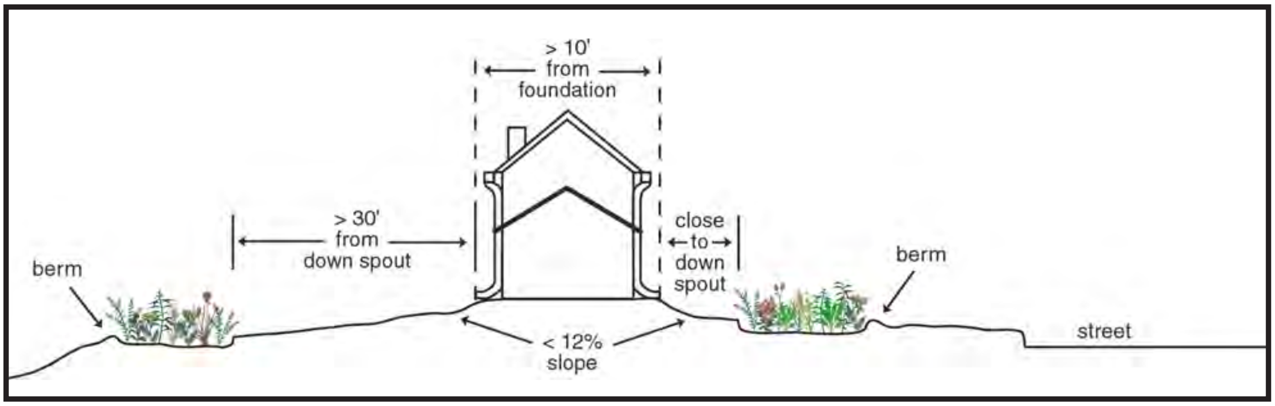


Figure 6.105 Rain Garden Schematic Diagram for Residential Applications.
Source: Wisconsin Department of Natural Resources

Site Location

Rain gardens should be placed in natural depressions or in areas where water will naturally collect. For example the lowest point of a catchment area where runoff is discharged from the rooftop. Or, stormwater can be routed to rain gardens in dryer locations, if increased groundwater recharge is the primary goal.

- Do not locate rain gardens within 10 feet of a building, because infiltration water can seep into the foundation.
- Do not locate rain gardens within 25 feet of lateral sewer lines, because they can increase the severity of inflow and infiltration into the sewer line. Sewer laterals are often located between the front of the house and the street.
- If the area naturally ponds for an extended period of time, additional engineering techniques will be needed to enhance drainage while maintaining the desired infiltration rate. Or the practice may need to be relocated.

A rain garden should have an area about 20 percent the size of the roof or driveway area draining into it. A typical rain garden for a residential home or small building is between 100 and 400 square feet. Rain gardens are often shaped longer than they are wide and positioned perpendicular to the slope of the land to maximize their function.

Pollutant Removal

Rain garden plants take up stormwater and pollutants such as:

- Heavy metals (e.g., copper, lead, zinc)
- Nutrients (e.g., nitrogen, phosphorous and potassium) and calcium.

The thin mulch layer and the engineered soil allow for quick infiltration of the stormwater. The mulch layer is exceptionally good at filtering out heavy metals from the stormwater. The soil layer filters heavy metals as well as nutrients, oil, grease and other pollutants.

Filtered stormwater percolates down to the gravel layer. The gravel stores some of the stormwater so it may continue to flow downward through the natural soil to the water table. The remaining water is re-released into the stormwater system via the underdrain if present. Rain gardens will vary in performance, based on accuracy and nature of design, installation and maintenance. More information about pollution control is available in the International Stormwater BMP Database at www.bmpdatabase.org/BMPPerformance.htm and in additional resources listed in Appendix C.

Ponding Volume and Conveyance

The ponding depth of a rain garden is typically between 4- and 6-inches. The garden should be designed to drain within two days in order to avoid nuisance insects. Exfiltration can be added where increased groundwater recharge is desired. Or, the filtered runoff can be collected in a perforated underdrain and returned to the storm drain system. The rain garden should be located relatively close to the source of runoff, but not too close to buildings or sewer laterals. The conveyance paths to and from the rain garden should be designed as part of the system, including an overflow drain if appropriate.

Rain gardens should be used to collect runoff from small areas such as:

- Rooftop runoff.
- Driveways.
- Small parking lots and similar areas.

They work best in a series of small runoff management practices if being used on larger sites. If the drainage area is too large, the rain garden will get overloaded and tend to clog.

Slope

A rain garden should be placed on a relatively shallow slope, where the slope of the surrounding watershed is limited to two percent to ensure an acceptable rate of flow into the garden area. Adequate slope is needed to ensure the water entering the rain garden can be connected with the storm drain system as necessary.

Soil

The proper design of a rain garden depends on the infiltration rate of the existing soil. If infiltration rates are less than ¼ inch per hour, the soil will need to be amended or completely replaced (engineered) to promote immediate infiltration. Engineered soil mixes are generally a homogenized mixture of equal parts of sand, topsoil and compost. Local jurisdictions may have specific requirements that should be reviewed.

Groundwater Recharge

Rain gardens are often constructed to reduce volume, rate and pollutant runoff. Design variations can be added to enhance groundwater recharge if desired or send overflow to the stormwater conveyance system if necessary. If the rain garden is designed and constructed properly to achieve infiltration, many of the small storms of concern (water quality storms) will not discharge at all. As a result, groundwater recharge will be a secondary benefit. Additional techniques and plant selection will need to be considered where groundwater levels might intersect the rain garden bed.

Plant Selection

Plant selection should include native or adaptive species tolerant of both wet and dry cycles. Deep rooted perennial plants are encouraged to increase the rate of infiltration. Larger plants have greater root capacity than smaller plants. Ponding creates conditions normally harsh to seed germination, therefore, rain gardens may need to be planted from root stock instead of from seed. Trees and shrubs may be used, but occasionally sod is used. Avoid planting evergreens if the area is to be used for snow storage, because salt can kill plants via roots that do not go dormant in the winter time.

Plants should be selected based on their native or adaptive status to the location. In Missouri, Grow Native! is an excellent resource for visual and narrative descriptions of native plants. For more information, see www.grownative.org. Many of these plants grow throughout the Midwest.

Costs

Rain garden costs will vary depending on the site preparation and plant selection. If the rain garden is excavated and new growing media installed, it will cibsust of one set of costs. If the rain garden is not excavated and is just amended, costs will be much lower, although the volume management will be impacted.

A general rule of thumb is that residential rain gardens average about $3 to $4 per square foot, depending on soil conditions and the density and types of plants used. Commercial, industrial and institutional site costs can range between $10 and $40 per square foot. For additional cost discussion and design tools, see LID Urban Design Tools at www.lid-stormwater.net/bio_costs.htm.

These costs should be weighed against costs for conventional stormwater management and its limitations for meeting water quality requirements. In addition, rain gardens can be incorporated into the landscaping, where operation and maintenance costs are relatively minimal. Rain gardens are designed to capture rainfall at the source of runoff, and therefore are strategically small and distributed. As landscaped features, less watering is required – especially when planted with deep-rooting native or adaptive plants. Rain gardens do not consume as much land area as a conventional detention basin. If designed, installed and maintained properly, a string of rain gardens can meet water quality requirements at a cost less than or equivalent to conventional detention basins that do not meet required water quality controls. In addition, costs to the municipality are reduced when proper owners assume responsibility for the minimal operation and maintenance. However, some cost is associated with keeping property owners educated about rain garden requirements.

Additional Considerations

Rain gardens do not provide significant channel protection, unless they are used in combination with other rain gardens or practices. A single rain garden is not designed to infiltrate large volumes. It is typically designed to treat and infiltrate the first inch of runoff. However, when used in combination with other rain gardens or practices, it can provide significant volume, rate and pollution reductions, thereby protecting channels as well.

Construction

Site Preparation and Grading

It is important to protect the designated location of the rain garden throughout the construction project. Avoid compacting the soil or creating other conditions unsuitable for supporting the rain garden.

An appropriate soil percolation rate should be established at each particular site. If the existing soils do not allow a sufficient rate of infiltration, a homogenized mixture of equal parts of sand, topsoil, and compost may be used in the rain garden to hasten infiltration. If there are concerns over long-term ponding as a result of low infiltration rates of the underlying soil, the site may need to be changed to be suitable for a rain garden. An underdrain may be used, although the relative cost of this added feature is often a concern.

Use river rocks or a filter strip to dissipate energy where water enters the garden.

- Design for rain gardens, rain barrels and cisterns should include an overflow point to accommodate severe rain events that may overload the system.

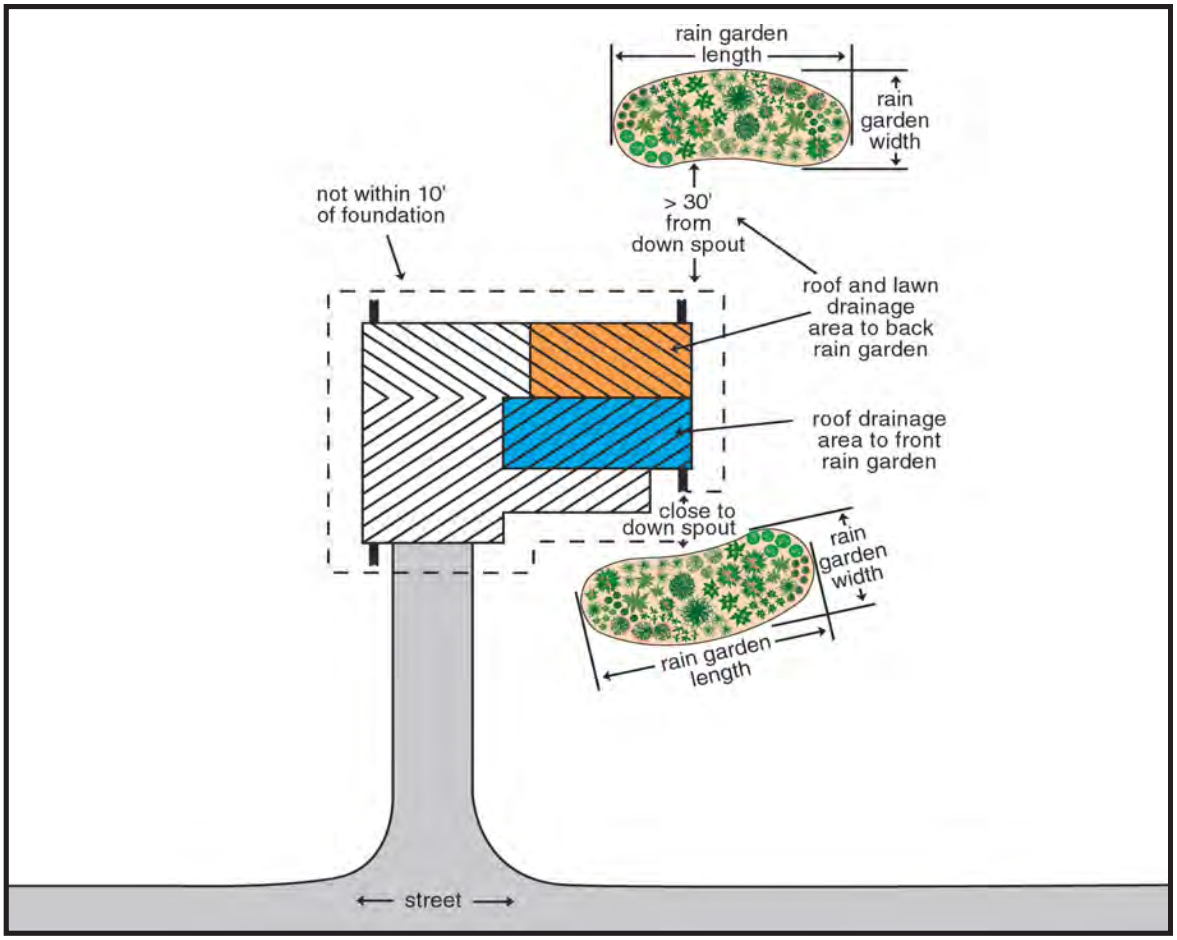


Figure 6:106 Rain garden schematic. Source: University of Wisconsin-Extension and the Wisconsin Department of Natural Resources.

Planting

- Construction and planting can be conducted year-round according to the plant type. The planting instructions for the plant should be followed.

Some engineered soil mixes may not provide sufficient strength for newly planted trees to stand in high winds. Tie straps may be needed or trees should be placed on the perimeter of the rain garden so their roots are anchored in stable soil.

Construction Verification

In the case of a professionally designed rain garden, measure the finished grades and configuration and compare them against the plans. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

The success of a rain garden depends on careful construction and on proper follow-up care, including:

- Watering and weeding often during first growing season.
- Annual removal of dead vegetation each spring.
- Annual addition of mulch, if needed.
- Periodic inspection for soil erosion control, plant health needs and litter removal, as needed.

Common Problems and Solutions

Problem	Solution
Erosion, washout and poor plant establishment.	Check to ensure the rain garden was constructed properly. Repair eroded surface, provide fresh topsoil, reseed or re-vegetate, and apply new mulch.
Mulch is lost to wind or stormwater runoff.	Reapply mulch, use a heavier inorganic mulch (pea gravel).
Unsuccessful vegetation establishment.	Recheck soil conditions for tilth and for conditions suitable for plant growth. Choose plant species that prefer the site conditions. Reset plants during an appropriate planting season. Reapply mulch.

Disconnected Downspouts

Figure 6.107 Downspout Disconnection to a Rain Garden. Source: Courtesy of USDA-NRCS, Iowa

Practice Description

Conventional structures direct the runoff from roofs into gutters and downspouts that then flows to a hard surface (parking lot), an underground storm sewer system and in some cases a sanitary sewer system. Routing stormwater from a hard surface to a discrete channel creates a flow surge. These surges can easily overwhelm storm or sanitary sewer systems. By disconnecting downspouts and routing flow to rain gardens or other pervious areas, runoff is redirected and may prevent the collection system from overloading during heavy precipitation events. Roof runoff can be beneficially used when redirected to a yard or landscaped area, rain garden or a storage system for later use (rain barrel or cistern). See Figure 6.107 and sections on rain gardens and rain barrels.

Recommended Minimum Requirements

Beneficial routing of downspouts may be applied to residential, commercial, industrial, or institutional properties. To ensure the designed routing of roof runoff does not result in other problems, the property owner should follow the guidance presented below:

- Discharge from pipe or downspout must not direct flow toward flood sensitive locations such as building foundations.

- Discharge point should be at least 10 feet from buildings and structures with basements or crawl spaces.

- Runoff should be discharged at least 5 feet from property boundaries, or at the furthest possible point from the adjacent property.
- Splash blocks or similar material may need to be used at the discharge point to dissipate erosive energy.
- Design for rain gardens, rain barrels and cisterns should include a designed overflow point to prevent damage to the system during severe rain events.
- Rain gardens, barrels or cisterns may need to be designed in combination across the property to attain desired reductions in volume and velocity and desired infiltration capacity.
- Discharge should be directed away from lateral sewer lines to avoid adding to inflow and infiltration problems.

Materials
Durable gutter grade materials such as aluminum, steel, copper, vinyl or plastic should be used.

Construction
Disconnecting downspouts can be simple or complex, depending on the site configuration, site requirements and goals. New projects can be readily designed to direct rooftop and similar runoff to rain gardens, barrels or cisterns. The site superintendent and field personnel should consult the site plan and specifications for direction about placement, special equipment and materials. To disconnect an existing downspout, most homeowners possess adequate skills to complete the project. See Appendix B and Appendix C for additional resources.

Installation
To disconnect an existing downspout, measure and cut approximately 9 inches above the sewer standpipe. The standpipe should be plugged or capped with an in-pipe test plug or an over the pipe cap secured with a hose clamp. An elbow and downspout extension may be secured with metal screws to the existing downspout. Downspouts must drain at least 6 feet from basement walls and at least 2 feet from crawl spaces. A splash block may be used at the end of the extension to help prevent erosion.

Maintenance and Inspection
Disconnecting a downspout typically requires minimal effort and minimal continued maintenance. Periodic maintenance activities include the following:

- Inspecting the discharge location to ensure drainage is working as intended.
- Replacing materials as needed; many materials can last 5 to10 years.
- Removing accumulated leaves or debris, 2 to 4 times per year.

Common Problems and Solutions

Problem	Solution
Foundation issues or water in the basement structure.	Downspouts must drain at least 10 feet from basement walls and at least 2 feet from crawl spaces.
Erosion where the downspout discharges.	A splash block may be used at the end of the extension to help prevent erosion.

Rain Barrels

Figure 6.108: Residential Rain Barrel. Source: *ABCs of MPs*

Practice Description

The roofs of many houses receive 600 to 1,000 gallons of water per one inch of rainfall. Rainwater falls on the roof, flows to the gutters and pours out of downspouts into the driveway or yard. Rain barrels intercept flow at the downspout, where it can be stored for use in watering nearby gardens or other landscape plantings. Usually the barrel is constructed with a 55 gallon drum, a flexible inlet pipe or hose, a spigot or closeable drain and a screen grate or closure to keep debris and insects out. Rain barrels are relatively simple and inexpensive to construct and can be placed under most residential gutter downspouts.

Recommended Minimum Requirements

Rain barrels may be applied to residential, commercial, industrial, or institutional properties. To ensure success, the property owner should follow the guidance presented below:

- Design for rain gardens, rain barrels and cisterns should include an overflow point to accommodate severe rain events that may overload the system.
- Locate the rain barrel directly under a downspout close to the structure.
- Carefully inspect screens to ensure mosquitoes cannot breed in barrels.
- Install a device to disconnect or divert water away during winter months to prevent damage from the freeze or thaw cycles.
- Provide an overflow that drains to a safe location.
- Direct overflow away from the foundation and away from lateral sewer lines.
- Secure the rain barrel to a level surface.
- Include a lid or screen that prevents the entry of mosquitoes and debris.

Construction

Installation of a rain barrel may be completed by homeowners, a property owner, or a qualified professional. Installation of a rain barrel should be in accordance with the critical elements described above. If the rain barrel is purchased from a retailer, it should be installed in accordance with the manufacturer's recommendations.

- The rain barrel should have an overflow that drains to a rain garden, bioswales or similar landscape feature.
- The rain barrel should be secured to a level surface.
- The barrel should have a lid that prevents the entry of mosquitoes and debris.

Installation

To install rain barrels on a new development, follow site plan specifications. When disconnecting an existing downspout, cut the downspout to the height necessary to accommodate the placement of the barrel. If the downspout entered a standpipe, the standpipe should be plugged or capped with an in-pipe test plug or an over-the-pipe cap secured with a hose clamp. An elbow and downspout extension may be secured with metal screws to the existing downspout and connected to the barrel. The overflow must drain at least 6 feet from basement walls and at least 2 feet from crawl spaces. A splash block may be used at the end of the extension to help prevent erosion.

Maintenance and Inspection

Installation of a rain barrel typically requires minimal effort and minimal continued maintenance. Periodic maintenance activities include the following:

- Checking the barrel and seals to ensure the system is working as designed and intended.
- Replacing materials or parts as needed.
- Removing accumulated leaves or debris a few times each year.

Common Problems and Solutions

Problem	Solution
Mosquitoes	Empty and clean the rain barrel. Ensure the screen (or spout-conformed lid) is properly in place and secured.
Foundation issues or water in the basement structure.	Route the overflow to drain further than 10 feet from basement walls and further than 2 feet from crawl spaces.
Erosion where overflows discharge.	A splash block may be used at the end of the extension to help prevent erosion

Cisterns

Figure 6.109: Residential Cistern. Source: Shockey Consulting Services

Practice Description

Practices that store rooftop runoff, such as cisterns or rain barrels can be installed as part of the overall on-site stormwater management system. A cistern collects and temporarily stores rain water runoff from an adjacent roof. Catchment capacity at many residential sites ranges between 600 to 1,000 gallons of water during a typical event. While cisterns may be applied to residential properties, their larger volume may make them especially beneficial in commercial or industrial settings where rooftops are expansive. Cisterns can be manufactured from various materials including plastic, concrete or metal. Installation costs are dependent on the material, size of application and location of the cistern (above or below ground).

Depending on local codes and available treatment methods, water collected in cisterns may be used in a variety of ways in the landscape and home. A common use is watering nearby gardens or other landscape plantings.

Recommended Minimum Requirements

Rainwater harvesting from rooftops is often considered pollutant-free, however, this runoff does contain low concentrations of pollutants such as plant debris, metals from roofing materials, nutrients from atmospheric deposition or bacteria from bird droppings. The levels of these pollutants are normally low enough to not inhibit its use for plant irrigation. Proper design and installation of the cistern will ensure problems relating to pollutants, such as system clogging, fouling, or odor, do not develop. Typically, rooftop runoff exiting the gutter system is screened to filter particles, before being routed to the cistern. Often, the design includes a method to prevent the initial flush of the roof, and its elevated amount of pollutants, from entering the cistern. Typically, collection containers should be constructed of dark materials or buried to prevent light penetration and the resulting algal growth.

Check the Uniform Plumbing Code or the International Plumbing Code; and regional and municipal building codes for criteria before initiating a rainwater harvesting project.

To ensure success, cistern construction should follow these important steps:

- For underground systems, the cistern should be a minimum distance of 100 feet from existing septic tanks and leach fields.
- Consider the depth of the water table when evaluating an underground system.
- Design of cisterns should include an overflow point to accommodate severe rain events that may overload the system.
- Choose appropriate cistern construction, drainage surfaces and filtering equipment to prevent contamination of the water supply.
- Ensure local requirements allow the construction and use of devices to catch and store rainwater.
- Review local codes for use and treatment of rainwater if its intended use is indoors.

Construction

Installation of a cistern may be completed by homeowners, a property owner, or a qualified professional.   Installation of a cistern should account for four components:

- Route overflow to a safe location.
- Secure the cistern to a level surface.
- Include a conformed lid or screen to prevent entry of mosquitoes and debris.
- Install a disconnect and draining feature for use during winter months to avoid freeze or thaw damage.

Installation

Because the size, shape, materials and operation methods of marketed cisterns will vary significantly, the plans and specifications or the manufacturer's guidance should be carefully reviewed before purchase and closely followed during construction and use.

Maintenance and Inspection

Maintenance and inspection of a cistern will vary depending on the systems design and the intended use of the rainwater. Periodic maintenance activities include the following:

- Periodic checks of the system to ensure it is working as designed and intended.
- Periodic replacement of materials or parts.
- Annual removal of accumulated leaves or debris or as needed.

Additional requirements for rain water collection and use may be imposed at the local level.

Common Problems and Solutions

Problem	Solution
Mosquitoes.	Empty cistern and clean. Ensure the screen is properly fitted, or install a solid lid conformed around the drain pipe.
Foundation issues or water in the basement structure.	Route the overflow to an outlet point at least 6 feet from basement walls and at least 2 feet from crawl spaces. Increase the distance as necessary.
Erosion where overflows discharge.	Use a splash block at the end of the extension to help prevent erosion.

Green Roofs

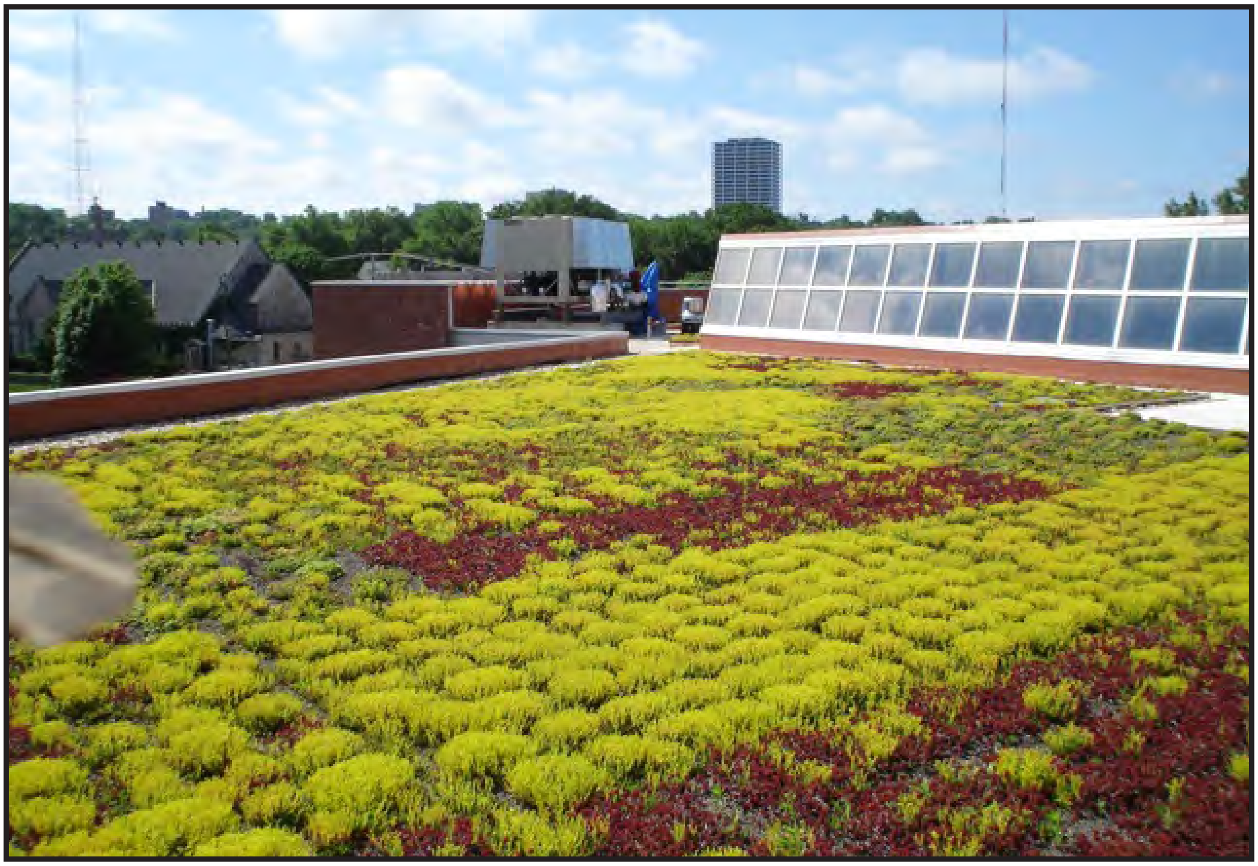


Figure 6.110: Boulevard Brewery, Kansas City, Missouri. Source: Boulevard Brewing Company

Practice Description

Green roofs are used to reduce stormwater runoff from commercial, industrial and residential buildings. In contrast to traditional roofing materials, green roofs absorb, store and evapo-transpire rainfall. Green roofs offer additional benefits including increased thermal insulation and energy efficiency, increased acoustic insulation and increased durability and lifespan.

These systems are generally classified as extensive, semi-intensive or intensive. Extensive green roofs have 6 inches or less of growing medium, whereas intensive green roofs have greater than 6 inches of substrate. Semi-intensive green roofs can be defined as a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is above or below the 6 inch depth. Semi-intensive and intensive green roofs are classified as roof gardens and are typically designed to be open to foot traffic for outdoor enjoyment.

Green roofs may be used in new construction or retrofitted to existing structures. They are applicable to residential, commercial and industrial buildings and can be constructed on roofs with up to a 20 percent slope. In retrofit applications, the existing roofing should be examined for adequate structural strength.

Pollutant Removal

According to *Opportunities and Challenges for Managing Nitrogen in Urban Stormwater: a Review and Synthesis* (see Appendix C and References), mature green roof vegetation can likely take up more nutrients from rainfall and media than younger, less established green roofs. Although there is a limited body of research available nitrogen removal capabilities of green roofs, studies suggest using low to medium dosages of controlled-release fertilizers, planting species that require little or no fertilization, using less nutrient-rich organic matter amendments in green roof media and reducing irrigation to avoid creating runoff can minimize the amount of nitrogen runoff. Consequently, additional pollutants of concern such as phosphorus will also be controlled.

Additional Considerations

Structural support is critical to increased media thickness necessary to promote denifriciation and therefore green roofs are generally not an option as a retrofit practice. Opportunities are greater for incorporating adequate support into new construction, but can add to the cost of materials by an estimated six percent. However, construction costs should be weighed against reduced heating and cooling costs, increased stormwater pollution control, reduced heat island effect and increased usable space in the case of rooftop gardens designed for social activity.

Recommended Minimum Requirements

In any application, the building must be able to support the loading of green roof materials under fully saturated conditions. An extensive vegetated roof cover is typically designed with 2- to 6-inches of engineered planting media. The media should have a high mineral content and is typically 85 percent to 97 percent non-organic materials. Fertilization should be tightly controlled on vegetated roofs intended to achieve water quality benefits, because over fertilization will defeat the purpose of pollution prevention from rooftop runoff. Internal building drainage should be addressed to ensure deck drains or scuppers are protected during large rain events. Typically, vegetated roofs are grown on conventional flat roofs. Assemblies planned for roofs with pitches steeper than 2:12 should incorporate supplemental measures to provide stability and prevent sliding. Generally, the designer should consider a waterproofing layer, a soil or substrate layer that has adequate pore space and rapid infiltration capacity, and a plant layer well-suited for local climatic conditions. Plant materials range from sedums, grasses and wildflowers on extensive roofs to shrubs and small trees on intensive roofs. The designer should consult local building codes for roof safety requirements. Necessary permits and zoning laws for building a green roof in new construction or as a retrofit to existing buildings will vary between cities.

Construction

Green roofs and roof gardens have a variety of benefits. Since this SCM integrates structural components, consultation of a design engineer is necessary. Projects should closely follow plans and specifications. The following provides an example of a construction sequence. Professional guidance or contract documents may dictate a different approach depending on the project.

- Comply with all building codes and local regulations.
- Visually inspect the completed waterproofing to identify any apparent flaws, irregularities, or conditions that will interfere with the security or functionality of the green roof. The waterproofing should be tested by the roofing applicator.
- Institute a leak protection program.
- Develop measures to protect the finished waterproofing from physical damage during construction.

- Install measures to stabilize the substrate in the case of a pitched roof slope.
- Install a root barrier, if the waterproofing materials are not impenetrable to roots.
- Install and test drainage and irrigation components, including drain access chambers, internal drainage conduit, confinement border units and isolation frames.
- Install walkways and paths for projects with public access. Ensure local codes are satisfied to ensure public safety.
- Install a drainage layer, such as a geocomposite drain mat or course of drainage media and cover the layer with a separation fabric such as a geotextile.
- Install and upper growth media layer in dual media assemblies.
- Establish plants from cuttings, seed, plugs or mats and select plants based on their toleration of periods of drought and inundation. Plant material is an integral component of a green roof.
- The contractor should provide protection from wind damage as warranted by the project conditions during the plant establishment period.

Construction Verification

Measure the finished grades and configuration against the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Green roofs need to be monitored regularly during the first growing season to ensure success. During the plant establishment period, periodic irrigation may be required. Quarterly maintenance during this period includes basic weeding and in-fill planting. Periodic inspection and roof maintenance should be performed as necessary to ensure the system is working as designed. Irrigated systems will require maintenance per manufacturer's recommendations.

Common Problems and Solutions

Problem	Solution
Insufficient vegetation.	Test irrigation and soil characteristics to ensure satisfactory growing conditions. Replace vegetation where absent. Ensure adequate inspection and maintenance.
Weeds and invasive vegetation during the establishment phase.	Remove manually. Plant adaptive and competitive species of vegetation to reduce bare areas and weed growth. Ensure adequate inspection and maintenance.

Surface Runoff Control Practices
Bioretention System

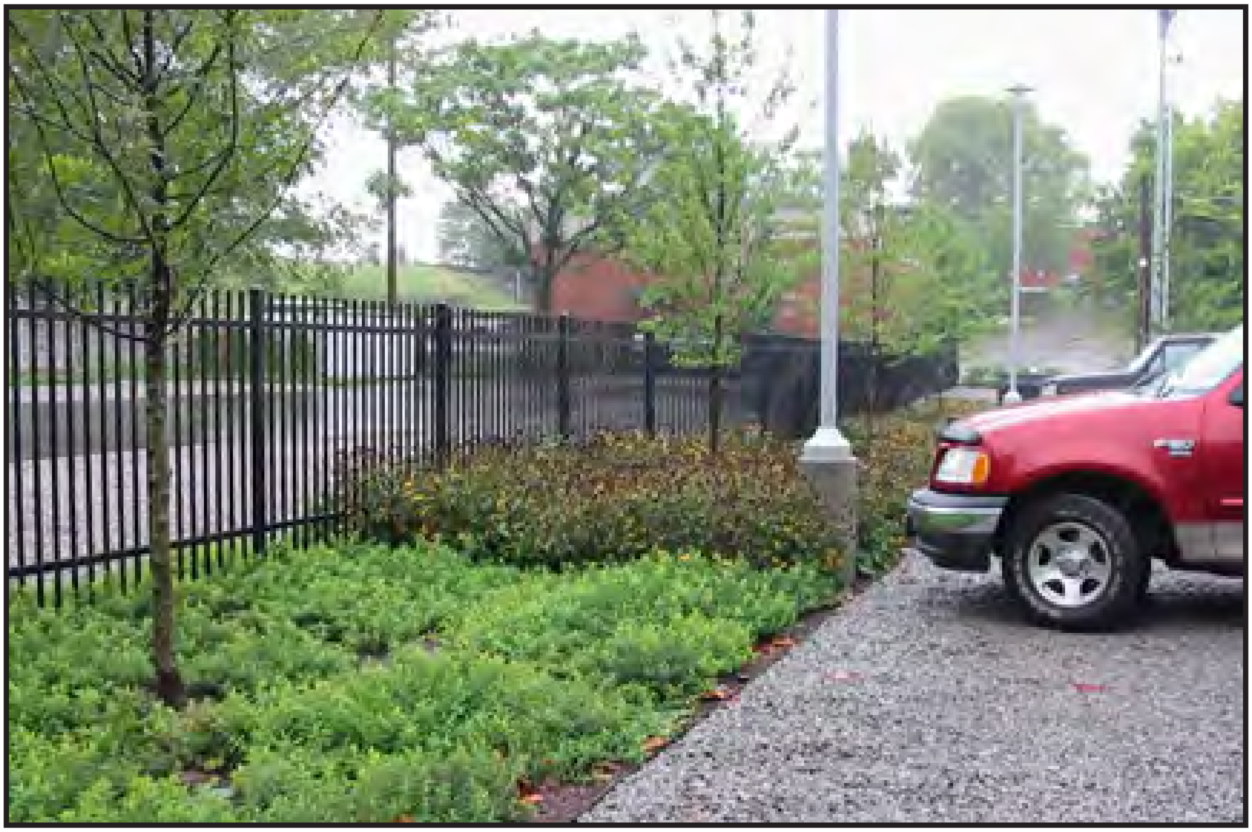


Figure 6.111: Bioretention. Source: *Green Infrastructure Digest*

Practice Description

A bioretention system is a landscaped parcel built into a natural or constructed depression; it is designed to provide on-site treatment of stormwater runoff. Bioretention systems can be located in parking lot islands or within residential areas. These systems are designed to incorporate many of the pollutant removal mechanisms that operate in natural ecosystems. During storm events, runoff water enters the bioretention system and filters through the mulch and prepared soil mix. The filtered runoff can be collected in a perforated underdrain and returned to the storm drain system. Excess runoff from larger storms is generally diverted past the facility to the storm drain system.

To achieve maximum efficiency, bioretention systems should be applied to small sites, typically less than a few acres. The drainage in larger sites should be portioned and served by more than one bioretention practice. Bioretention systems are ideal for treating runoff in urban areas and can easily be incorporated into parking lot islands or other landscaped areas. Bioretention areas may be used to treat stormwater from highly polluted areas, however, in this case, an impermeable liner may be needed below the filter bed to prevent the infiltration of pollutants into the deeper soil layers.

Recommended Minimum Requirements

Bioretention systems are adaptable to most sites and blend well with buffers, landscape berms, and environmental setback areas. The site layout of a bioretention system should be based on the contributing drainage area, underlying soils, utilities and existing vegetation. A bioretention cell should have an underdrain system, overflow, aggregate filter, planting soil bed, a mulch layer and plants that can withstand periods of inundation and drought. A bioretention cell should be designed to capture the water quality volume and to filter this water through the planting soil bed over 1 to 3 days. The cell of adequate length and width should be strategically positioned against the slope in order to maximize the capture of runoff. Inflow velocities should be reduced to less than 3 feet per second upstream of the area. Typically, a vegetated filter strip or rock diaphragm is required to reduce runoff velocities and provide a level of pretreatment. The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation.

Construction

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process.

Site Preparation and Grading

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

The bioretention cell can be excavated before final stabilization of the surrounding watershed; however, the soil mixture and underdrain system should not be placed until the entire contributing drainage area has been stabilized. Any sediment from construction operations deposited in the bioretention cell should be completely removed from the cell after all vegetation, including landscaping within the affected watershed, has been established. Excavations performed during the construction of the cell should be limited to only that necessary to create the cell and to blend the cell with the surrounding watershed. Final graded dimensions, side slopes, and final elevations should be constructed according to design drawings and specifications. Low ground-contact pressure equipment, such as excavators and backhoes, is preferable to minimize disturbance of established areas around the perimeter of the cell. No heavy equipment should operate within the perimeter of a bioretention cell during underdrain placement, backfilling, planting or mulching of the facility.

The final steps to creating the bioretention cell should include stabilizing all surfaces and beginning a regular inspection and maintenance program.

Installation

The basic components of installing a bioretention cell include an underdrain system, overflow, aggregate, planting soil bed, a mulch layer and plant establishment.

Underdrain

An underdrain increases the ability of the soil to drain quickly and therefore ensures an adequate aerobic state that allows plants to grow. A minimum 4-inch perforated pipe with an 8- to 12-inch gravel bed should be installed as an underdrain system. At least one cleanout should be installed every 50 feet on each run. The underdrain should be connected to a up-to-date stormwater management system with adequate capacity or daylight to a suitable outfall with erosion protection. Before placing the aggregate, underdrain and bioretention soil mixture, the bottom of the excavation area should be roto-tilled to a minimum depth of 6-inches to alleviate any compaction that might impede infiltration. The soil should be in a friable condition before any roto-tilling occurs, meaning the soil can be reduced to smaller pieces with little effort, and therefore isn’t susceptible to clumping or compacting.

Overflow

Overflow components of the bioretention cell include the gravel underdrain system, an aggregate overflow curtain drain, and a high-flow overflow structure. A properly designed overflow will prevent a washout of the cell's components or a reconcentration of flow.

Aggregate Versus Sand

Aggregate provides a greater porosity and is less likely to clog when compared to a sand bed. A graded aggregate filter is preferred over soil, sand, pea gravel and course gravel. If a soil surface for planting is desired, a geotextile fabric should separate the soil from the aggregate. Alternatively, a sand bed can be used underneath the soil bed. The aggregate or sand provides additional filtration, allows aeration of the planting soil bed and therefore does not need to be separated from the soil by a geotextile fabric.

Planting Soil

A planting soil bed is a mixture of organic mulch, planting soil and sand. Typically, the mixture consists of 30 percent planting soil, 20 percent organic compost and 50 percent sand. Clay should be limited to less than 10 percent. To enhance nutrient uptake, the soil must have chemical and physical properties suitable to support a diverse microbial community. The planting soil should be placed on top of the aggregate or sand layer, and should be separated with a geotextile fabric. It should have a minimum depth of 2.5 feet to provide adequate moisture capacity and create space for the root systems of plants. If larger vegetation is used (i.e. trees or shrubs), the planting soil must be at least 4-inches deeper than the bottom of the largest root ball. This soil mix will tend to not be as firm as natural soils, so larger trees or shrubs should be supported with guy wires or similar support. The planting soil mixture, alternately called the bioretention soil mixture, should be free of stones, stumps, roots, or weedy material over 1-inch in diameter. Brush or seeds from noxious weeds should not be present in the material.

A simple bio-soil permeability test is to use a 55-gallon drum with holes in the bottom. Fill the bottom of the drum with the proposed mix until it is 1-foot from the top. Fill the barrel to the top with water and time how long it takes the water to drop 1-foot.   A target rate of 2-inches per hour is common.

Plants

Trees, shrubs and other plant materials should be installed as specified in the project plans and according to applicable landscape standards with the exception that pesticides, herbicides and fertilizer should not be applied during planting under any circumstances. Pesticides, fertilizer and other soil amendments should be applied after plants are through initial shock and are growing. Plant selection should include native species tolerant of both wet and dry cycles.
Deep rooted perennials are encouraged to increase the rate of infiltration

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region.   See additional plant information resources in Appendix C.

Mulch

The final layer of the bioretention cell is the mulch. The contractor should install a shredded hardwood mulch aged a minimum of six months and consists of a 50/50 combination of bark and wood from hardwood trees. The mulch should be milled and screened to a maximum 4-inch particle size and should be free from sawdust, clay, trash and any artificially introduced chemical compounds.

Construction Verification

Measure the finished grades and configuration and compare to plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

For the first 1 to 3 years, bioretention systems require significant maintenance to ensure successful establishment. The primary maintenance requirement is inspection, repair and replacement of damaged or failed components. Routine inspections for standing water and corrective measures to restore proper infiltration rates are necessary. Invasive or weedy vegetation should be removed immediately upon discovery. During the first growing season, watering and weeding should be completed on a weekly basis. Over the lifetime of the facility, dead vegetation should be removed and mulch should be added each spring. Annual maintenance should include periodic inspection of soil erosion and plant health, as well as removal of litter when necessary.

Common Problems and Solutions

Problem	Solution
Erosion, washout and poor plant establishment.	Check topsoil and repair eroded surface. Reseed or re-vegetate and apply new mulch.
Mulch is lost to wind or stormwater runoff.	Reapply mulch, consider inorganic mulch in some areas.
Cells collect trash and debris.	Typical maintenance.
Standing water.	Check underdrains for clogging. Incorporate additional aggregate or sand into the soil mixture.
Unsuccessful vegetation establishment.	Examine the cell for stress factors (e.g, extended pooling, low fertility in planting medium, wildlife damage) and take corrective action.
Tall, lanky native plants.	Consider soil combinations more conducive to native plant growth in the original design. Amend the soil as necessary.

Bioswales (Vegetated Swales)

A bioswale or vegetated swale is an infiltration and filtration method typically used to pre-treat urban stormwater runoff. Bioswales can have volume and pollution reduction effects. There are generally three types of vegetated swales referred to as urban runoff management options:

- Dry swales with filter media.
- Wetland swales.
- Turf swales.

When determining whether to use a bioswale or other technology in overall site design, consideration should be given to the drainage area size, impervious area and water quality goals. Water quality swales should be used in areas where either the drainage area is small, or the impervious area is small, or both. Otherwise, larger conveyance design storms become incompatible with the features needed to provide water quality benefit (e.g., vegetative filtering, erosion).

The main difference between a bioswale and bioretention is that bioswales have a conveyance function for storms greater than the small storm (water quality storm). (See Bioretention Systems.) A standard bioretention system or cell does not have a conveyance function, but rather a bypass (overflow inlet) for greater storms. Wetland swales, as well as wetlands, are preferred in areas where groundwater stays charged enough to support the diverse group of wetland plants. However, wetlands are preferred over wetland swales where there is a greater need for volume reduction in addition to water quality.

All swale designs need to include a hydraulic analysis of the swale during larger storm events. The design of the larger storm events should be based on local conveyance requirements, which are typically a 10- or 15-year storm event. Many communities also have a freeboard requirement, which means the maximum water surface elevation for the design storm should be so many feet below the top of the channel, depending on the design specifications. For example, the freeboard requirement throughout St. Louis County, MO is 1-inch, but sometimes the requirement is waived for smaller “basins” depending on the risk of an overtopping event.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design, St. Louis, Missouri*. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Dry Swale

Figure 6.112 Native Parking Lot Bioswale. Anita B. Gorman Conservation Discovery Center - Kansas City, Missouri.
Source: Copyright © Missouri Conservation Commission. All rights reserved - used with permission.

Practice Description

Dry swales are broad and shallow channels with vegetation covering the side slopes and channel bottom. These swales use native or adaptive plant species, and unlike the wetland swale include an engineered soil mix, a graded filter and an underdrain system for drainage to promote growth of dry swale plants. They are similar to wetland swales in that they convey stormwater runoff slowly, promoting infiltration and treatment. Their broad, shallow, vegetated channels promote infiltration, plant transpiration, adsorption, settling of suspended solids and breakdown of pollutants.

Dry swales can replace curb and gutter storm sewer systems to convey shallow concentrated flow. These swales promote infiltration and filter pollutants through creating low (slow flow) gradients, using soil and mulch to promote pollutant absorption and dense plant growth, and establishing plant species that can biologically uptake soluble pollutants. This SCM often enhances the aesthetic value of a site with minimal maintenance. It is particularly applicable in natural depressions adjacent to roads.

Recommended Minimum Requirements

The dry swale should be planted with dense, low-growing native or adaptive vegetation that can withstand periods of inundation and drought, and be salt tolerant. Longitudinal slopes should range between one and six percent and side slopes should be between 3:1 and 5:1 (horizontal distance to vertical rise referred to as H:V). Check dams may be used to provide limited detention storage and to develop a milder slope. The bottom width of the swale is typically less than 8-feet but may be sized to convey flow as required. The swale should be sized to convey the design storm event with a minimum of 6-inches of freeboard.

To determine the optimal location for a dry swale, soil conditions and compaction should be tested. Swales provide the most benefit when located adjacent to an impervious surface but can be used in combination with porous pavement. The designer should review local requirements for site grading, erosion and sediment control, and potential invasive vegetation.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design, St. Louis, Missouri*. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

Figure 6.113: Native Vegetated Swale Source: EDAW, EACOM

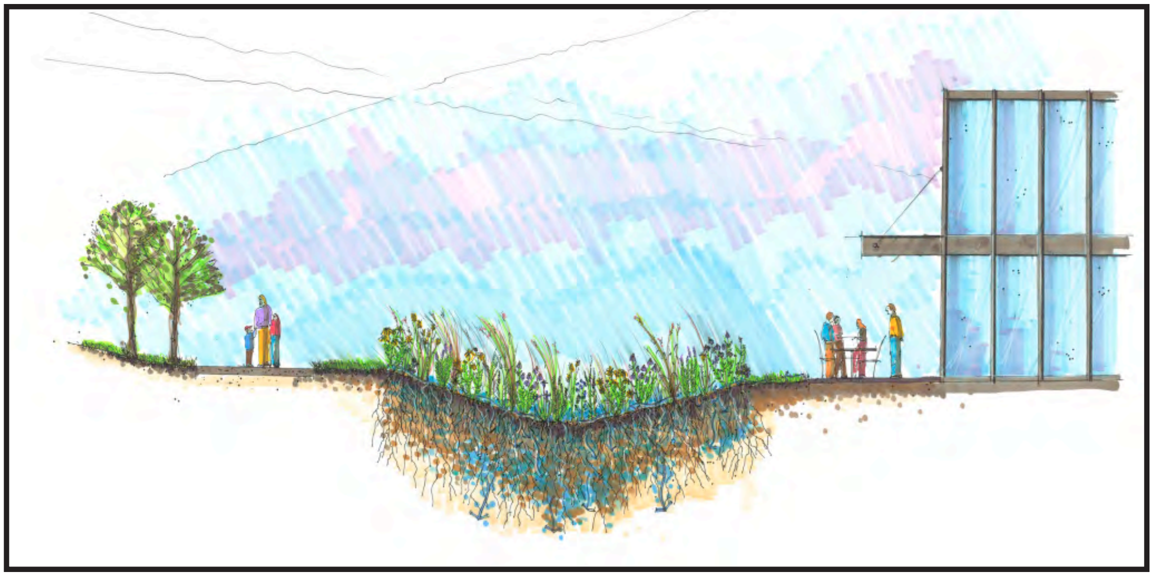


Figure 6.114 Bioswale Cross-sectional Diagram   Source: NRCS, Iowa, www.ia.nrcs.usda.gov

The dry swale construction should begin only when upgradient temporary erosion and sediment control measures are in place to prevent sediment laden stormwater from depositing unwanted soil into the swale and reducing the infiltration efficiency. An example construction sequence follows:

- Rough grade the swale. It is critical excessive compaction or land disturbance be avoided when parking or using equipment, otherwise it will be necessary to amend or replace compacted soils. Excavating equipment should operate from the side of the swale and never on the bottom.

- The underdrain should be installed after the site has been rough graded. An underdrain increases the ability of the soil to drain quickly and therefore ensures an adequate aerobic state that allows plants to grow. A minimum 4-inch perforated pipe with an 8-inch gravel bed should be installed as an underdrain system. Filter fabric should be placed over the gravel bed to separate it from the planting soil bed. At least one cleanout should be installed every 50 feet. The underdrain should be connected to a conventional stormwater management system (pipes) or to an open conveyance (daylighted) to a suitable outfall with erosion protection.

- The overflow components of the bioswale include the gravel underdrain system and a high-flow overflow structure. It is critical to provide a safe discharge point for overflows.

- Install the aggregate or sand layer. Aggregate provides a greater porosity and is less likely to clog when compared to a sand bed. It is acceptable to place an 8-inch layer of aggregate underneath the planting soil bed, when it is separated by a geotextile fabric.

- Install the planting soil with careful attention to match the design grading. A planting soil bed is a mixture of organic mulch, planting soil, and sand. Typically, the mixture consists of 30 percent planting soil, 20 percent organic compost, and 50 percent sand. To enhance nutrient uptake, the soil must have a combination of chemical and physical properties that have the capacity to support a diverse microbial community. The planting soil should be placed on top of the aggregate or sand layer, separated by a geotextile fabric. The planting soil mixture, sometimes called a bioretention soil mixture, should be free of stones, stumps, roots or weedy material more than 1-inch in diameter. Brush or seeds from noxious weeds should not be present in the material.

- Seed, vegetate and install protective lining according to the plans and final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation, however, may be needed in periods of drought. Vegetation should be established as soon as possible to prevent erosion and scour.

  For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is important for the swale to be stabilized before receiving upland flow.

Construction Verification

Measure the finished grades and configuration and compare with the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

The required maintenance associated with bioswales is minimal. Typically, maintenance strategies for swales focus on sustaining the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a diverse vegetative cover. Specific maintenance activities should occur within 48 hours after every storm event greater than a 1-inch rainfall until the plantings and vegetation are fully established. The maintenance activities should include:

- Repair erosion problems, damage to vegetation and remove sediment and debris accumulation.
- Vegetation on the side slopes should be inspected for erosion and formation of rills and gullies.
- Pools of standing water should be dewatered and discharged to an approved location and the design grade should be restored.
- Vegetation should be mowed or trimmed, as necessary to ensure safety, aesthetics, or to suppress weeds and invasive vegetation.
- The uniformity of the swale cross section and longitudinal slope should be inspected.
- The swale inlet and outlet should be inspected for signs of erosion or sediment accumulation.

Other maintenance activities should be completed as needed:

- Alternative vegetation may be planted if the existing vegetation is not thriving.
- Bare areas should be reseeded or revegetated and the appropriate erosion control measures should be installed when soil is exposed.
- During the period of establishment, the swale may need to be watered during dry periods.

Depending on the characteristics of the contributing drainage area, winter conditions may necessitate additional maintenance. The swale should be inspected at the beginning of spring for residuals of sand or salt. Moderate amounts of these materials might affect vegetative growth. Damaged vegetation should be replaced. If roadside or parking lot runoff drains to the swale, mulching or soil aeration may be required in the spring to restore the soil structure.

Common Problems and Solutions

Problem	Solution
Draw down time is greater than 72 hours.	Clean out underdrain system, ensure it is clear.
Erosion occurs on the side slope and bypasses the check dam.	Increase the length of the check dam so the lowest point is in the center of the swale.
Significant erosion between check dams.	Install additional check dam and follow recommended guideline for spacing.
Poor vegetative growth due to roadway salt accumulation.	Use nontoxic deicing agents, applied as blended magnesium chloride based liquid or as pretreated salt. Plant salt tolerant vegetation. Avoid evergreens, because roots that do not go dormant are susceptible to salt kill.
Unsuccessful vegetation establishment due to plant intolerance to conditions.	Plant selection should include native species tolerant of both wet and dry cycles and plants should be established in appropriate zones. Deep rooted perennials are encouraged to increase the rate of infiltration.

Wetland Swale

Figure 6.115: Wetland Swale. Source: Olsson Associates

Practice Description

Wetland swales are broad, shallow channels with native vegetation covering the side slopes and emergent vegetation covering the channel bottom. Unlike a dry bioswales, these swales do not include a prepared soil filter bed or underdrain system. Stormwater runoff is slowly conveyed resulting in higher rates of infiltration, plant transpiration, pollutant adsorption, settling of suspended solids and microbial breakdown of pollutants.

Wetland swales can replace curb and gutter storm sewer systems and may be used anywhere the water table is at or near the surface. These swales are well suited for roadside applications, along the property boundaries of development or in areas where stormwater tends to collect for extended periods of time.

Recommended Minimum Requirements

The wetland swale should be planted with dense, low-growing native vegetation that can withstand periods of inundation, drought and soils with high electrical conductivity (high salt content). Longitudinal slopes should range between one and six percent and side slopes should be between 3:1 and 5:1 (H:V). Check dams may be used to provide limited detention storage and to develop a slower flow rate. The bottom width of the swale should be between 2- and 8-feet. The swale should be sized to convey the largest/average 24-hour, 10- to 15-year storm event with a minimum of 6-inches of freeboard (based on local conveyance requirements).

To determine the optimal location for a wetland swale, soil conditions and compaction should be tested. Swales provide the most benefit when located adjacent to an impervious surface but can be used in combination with porous pavement. The designer should review local requirements for site grading, erosion and sediment control, and potential invasive vegetation.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Pollutant Removal

The wetland swale has water quality treatment mechanisms similar to stormwater wetlands, which rely primarily on settling of suspended solids, adsorption and uptake of pollutants by vegetative root systems. Chloride contamination of shallow groundwater tables should always be of concern in the design and application of wetland swales.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

The wetland swale is constructed directly within existing soils and may or may not intercept the water table. Like the dry swale, the water quality volume within the wet swale should be stored for approximately 24 hours. The wetland swale has water quality treatment mechanisms similar to stormwater wetlands, which rely primarily on settling of suspended solids, adsorption, and uptake of pollutants by vegetative root systems. These systems are often called wetland channel systems since they are basically a linear shallow wetland system.

The wetland swale construction should begin only when the upgradient temporary erosion and sediment control measures are in place. An example construction sequence follows:

- Rough grade the swale. Equipment should avoid excessive compaction or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to compaction of the subgrade, 18-inches should be removed and replaced with a blend of topsoil and sand to promote infiltration and the establishment of plants and microbes. Topsoil shall be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

- Construct check dams, if required.

- Fine grade the swale. Accurate grading is critical for swales because even the smallest nonconformities may compromise flow conditions.

- Seed, vegetate and install protective lining as per approved plans and according to final planting list. Plant the swale at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation, however, may be needed in periods of drought.

- Vegetation should be established as soon as possible to prevent erosion and scour, however it make take a few years for plants to become fully established.

After all tributary areas are sufficiently stabilized, temporary erosion and sediment controls may be removed. It is important for the swale to be stabilized before receiving upland flow.

Maintenance and Inspection

The required maintenance associated with wetland swales is minimal. Typically, maintenance strategies for swales focus on sustaining the preferred hydraulic flow and pollutant removal efficiency of the channel, as well as maintaining a higher biological richness through promoting microbial growth and a diverse vegetative cover. The following maintenance activities should occur within 48 hours after every storm event greater than 1-inch rainfall.

- Repair erosion problems, damage to vegetation and remove sediment and debris accumulation.
- Vegetation on the side slopes should be inspected for erosion and formation of rills and gullies.
- Pools of standing water should be dewatered and discharged to an approved location and the design grade should be restored.
- Vegetation should be mowed or trimmed, on an annual basis, as necessary to ensure safety and aesthetics, or to suppress weeds and invasive vegetation. Mowing equipment should avoid wet areas where compaction of the swale and erosion would be potential issues.
- Use wet tolerant plants in the bottom of the swales so the area will not be bare or begin to collect sediment. See available plant resources in Appendix C.
- The uniformity of the swale cross section and longitudinal slope should be inspected.
- The swale inlet and outlet should be inspected for signs of erosion or sediment accumulation.

Other maintenance activities should be completed as needed:

- Alternative plant species may be planted if the existing vegetation is not thriving.
- Bare areas should be replanted and the appropriate erosion control measures should be installed when soil is exposed.
- If the drawdown time is greater than 48 hours, the swale should be roto-tilled and replanted.
- Check dams should be repaired if channelization and erosion are identified.
- During the period of establishment, the swale may need to be watered during dry periods.

Depending on the characteristics of the contributing drainage area, winter conditions may necessitate additional maintenance. The swale should be inspected at the beginning of spring for residuals of sand or road salt. Moderate amounts of these materials may affect the plant and microbial growth. Damaged vegetation and contaminated soils should be replaced. If roadside or parking lot runoff drains to the swale, mulching or soil aeration may be required in spring to restore the soil structure.

Common Problems and Solutions

Problem	Solution
Erosion occurs on the side slope and bypasses the check dam.	Increase the length of the check dam so the lowest point is in the center of the swale.
Significant erosion between check dams.	Install additional check dam and follow recommended guideline for spacing.
Poor vegetative growth due to roadway salt accumulation.	Use nontoxic deicing agents, applied as blended magnesium chloride based liquid or as pretreated salt. Plant salt tolerant vegetation. Avoid evergreens, because roots that go dormant in the winter time can take up salt and kill the plants.
Unsuccessful vegetation establishment due to plant intolerance to conditions.	Plant selection should include native or adaptive species tolerant of both wet and dry cycles. Plants should be established in appropriate climate zones. Deep rooted perennials are encouraged to increase the rate of infiltration.

Turf Swale

Figure 6.116 Turf Swale. Source: N. Klopfenstein, NRCS, Cole County

Practice Description

A turf swale is also referred to as grass-lined channel, grass waterway or grass swale, and it differs from dry or wet bioswales in that no special provisions or materials are included to maximize infiltration or pollution reduction.

Typically, an objective for constructing a turf swale is for the purpose of handling concentrated surface runoff in such a way as to prevent damage from erosion and the resulting sedimentation downgradient. However, turf swales offer the least amount of water quality and volume control when compared to other bioswales or bioretention options.

This practice has historically been used for sites where:

- Concentrated runoff is expected to cause erosion damage.
- Sufficient stability for the channel can be achieved through a vegetative lining.
- Channel grades are generally less than 5 percent.
- Significant space is available to allow for a sufficient channel width for gentle side slopes.

However, this practice is basically a conveyance ditch, which does not serve as a stormwater control measure adequate to control peak flow for water quality or design storms. If used at all, this practice should be limited to linear projects.

Typical uses include roadside ditches, channels at property boundaries, outlets for diversions and stabilizing concentrated flow areas. The grass-lined channel will provide better infiltration and greater root structure if the vegetation is allowed to grow to its full height and not mowed short, serving more as a vegetated dry swale described previously in this section. Selective native or adaptive grasses can provide a functional root depth up to 15 feet, whereas mowed turf grasses provide 1- to 2- inches of root structure. Colored photos and specifications of Missouri native plants are available at www.grownative.org.

Recommended Minimum Requirements

Prior to start of construction, grass-lined channels should be designed by a registered design professional as part of the overall site design for stormwater management. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The channel should be built according to planned alignment, grade and cross section. Some of the typical features are:

Cross Section

Trapezoidal or parabolic.

Side Slopes

3:1 or flatter for trapezoidal channels.

Channel Stabilization

Use erosion control blankets, turf reinforcement mats or other appropriate practices as specified in the design plan.

Outlet

Channels should empty into sediment traps, detention/ retention basins or stable outlets.

Subsurface Drain

Use in areas with seasonally high water tables or seepage problems.

Construction

Site Preparation

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Install sediment traps or drains if needed. Remove brush, trees and other debris from the construction area and dispose of properly.

Grading

Excavate and shape the channel to dimensions shown on the design specification, removing and properly disposing of excess soil so surface water can enter the channel freely.

If a subsurface drain is needed, install it as designated in the plans.

Provide topsoil as needed to enhance the growth of grass within the channel.

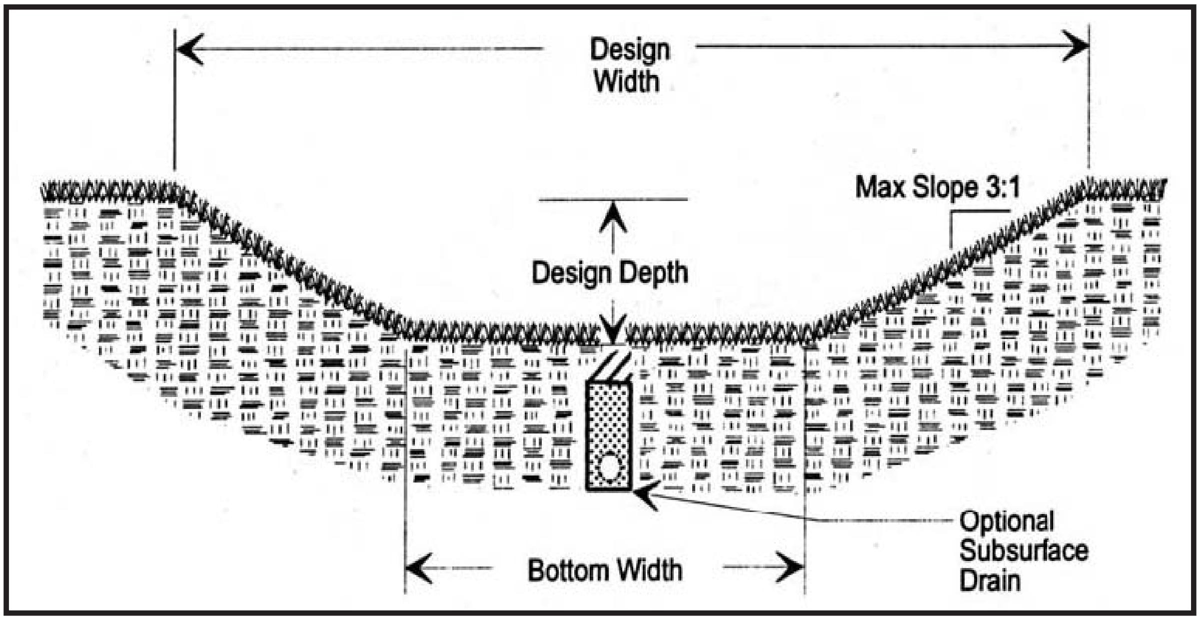


Figure 6.117 Typical Trapezoidal Turf Swale. Source: St. Charles County Soil and Water Conservation District, Missouri

Erosion Control

Protect all concentrated inflow points along the channel with erosion-resistant linings, sod or other appropriate measures.

Fertilize and seed or sod the channel immediately after grading and protect with erosion control blankets, turf reinforcement mats or mulch according to the design plan.

Channel should outlet at a stable location.

Construction Verification

Check finished grade and cross section of the channel throughout the length of the watercourse. Verify the evenness of channel cross sections at several locations to ensure sheet flow.

Maintenance and Inspection

- Inspect the channel following storm events both during and after grass cover is established; make needed repairs immediately.
- Check the channel outlet and road crossings for blockage, sediment, bank instability, breaks and eroded areas. Remove any blockage and make repairs immediately.
- Remove significant sediment and debris from the channel to maintain design cross section and grade, and to prevent spot erosion.
- A specific operations and maintenance plan should be provided by the design professional and transferred to the person responsible for long-term operations and maintenance. Adequate training should be provided as well.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate the channel will not function as intended. Changes in plan may be needed.	Consult with the registered design professional.
Erosion occurs in the channel before vegetation is fully established, due to lack of adequate controls above the channel.	Establish controls above the channel. Repair, reseed and install erosion control blankets or turf reinforcement mats.
Gullying, head cutting or settling in the channel due to overly steep grade or improperly placed drain.	Refer to design specifications or design professional to ensure proper design or re-design of the channel, use erosion-resistant lining and ensure drain is properly placed (typically on the side for post-construction versus at the bottom during construction.)
Overbank erosion, spot erosion, channel meander or flooding occurs due to instability.	Remove accumulated debris and sediment, stabilize and revegetate trouble spots.
Side slope caves in as a result of unstable, high-water-table soil, steep banks or high-flow velocity. Most likely to occur on the outside of channel curves.	An alternate practice may be more appropriate, such as a wetland or wetland swale. Consult with the design professional.
Ponding along the channel due to improperly graded approach or blocked surface inlets.	Improve the channel grade or remove blockage.
Erosion at the channel outlet due to instability.	Install an outlet stabilization structure.
Sediment deposited at the channel outlet due to unidentified channel or watershed erosion.	Find and repair the source of any channel erosion and stabilize the drainage area with permanent practices professionally designed to protect water quality.
Design specifications for seed variety, seeding dates or erosion control materials cannot be met.	Substitution may be required. Unapproved substitutions could result in channel erosion.

Dry Pond (Detention)

Figure 6.118 Dry Pond. Source: ABC's of BMP's, LLC

Practice Description

A dry pond is a surface storage basin or facility designed to provide water quantity control and limited water quality benefits through stormwater detention or extended detention. Dry ponds, also known as dry detention basins or dry detention ponds, are ponds designed to store and then release stormwater runoff from a specified design rainfall event. Unlike wet ponds, dry ponds do not have a permanent pool.

The historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff – essentially providing flood control.   These types of dry ponds seldom meet the overall quantity and quality objectives as a stand alone practice.   Flood detention ponds were not designed to detain stormwater from small flow events.

Variations of dry ponds include:

- Dry pond for peak flow rate (flood) control only (Figure 6:118).
- Extended detention dry pond for limited water quality control and for channel protection .
- Combination dry pond – combining flood control with extended detention.

Sometimes a dry pond is an acceptable option for achieving flood detention. However, volume reducing (i.e., retention) practices are preferred over flood detention practices as a method of flood control in the lower portion of a major watershed or drainage basin. A dry pond should also be a last resort option in the upper portion of the watershed, because many alternative practices are available to simultaneously reduce volume, protect against flooding and achieve water quality. As an example, Figure 6:119 illustrates a similar 100-year flood detention benefit is achieved by retaining 1.1-inches of rainfall retention in multiple mircoscale practices across a residential development.

Given adequate space in the urban environment, dry ponds can be used to retrofit a drainage area to provide flood control, channel protection and in some cases temperature control. As noted above, it is also important to note where in the major watershed the detention basin is located. As a rule of thumb, detention basins are most effective when placed in the upper 1/3 of a major watershed. Otherwise, detention basins provided in the lower portion of the watershed will likely release water at the same time flow from the upper portion of the watershed reaches the same point. This can make downstream flooding and erosion problems worse by forcing even larger volumes of water into the downstream channel.

Dry ponds are sometimes converted from construction site sediment basins through the removal of sediment, addition of vegetation and modification of the basin outlet structure. Dry ponds are permanent “post construction” ponds as opposed to a sediment basin, and therefore should not be designed or used to store construction site sediment.

Dry ponds should not be put into use until after all construction is complete and the site is completely stabilized. These ponds detain the stormwater flow from rain events but do not hold it for long periods of time. These are designed to be fully vegetated on bottom and side slopes. The outlet structure is designed and built at the lowest point in the basin, allowing the basin to fully drain. Dry ponds should be constructed so all stormwater is detained, not retained as in a retention or “wet” pond.

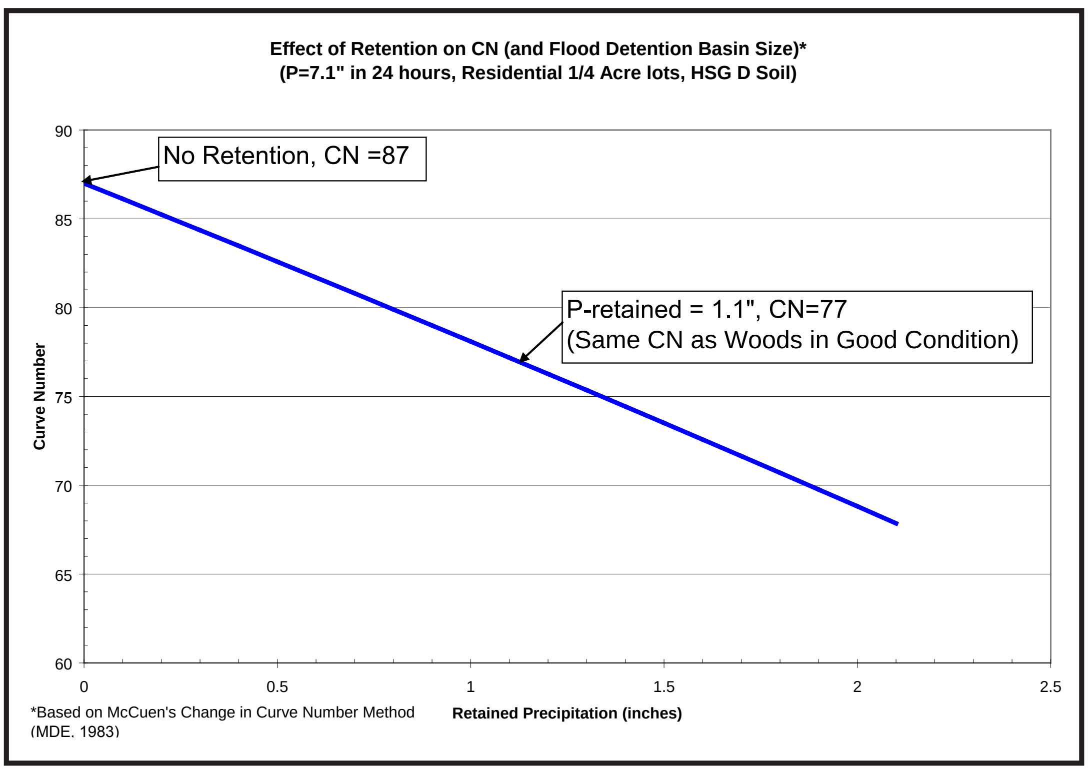


Figure 6.119 Effect of retention on curve number (and flood detention basin size). Source: Metropolitan St. Louis Sewer District

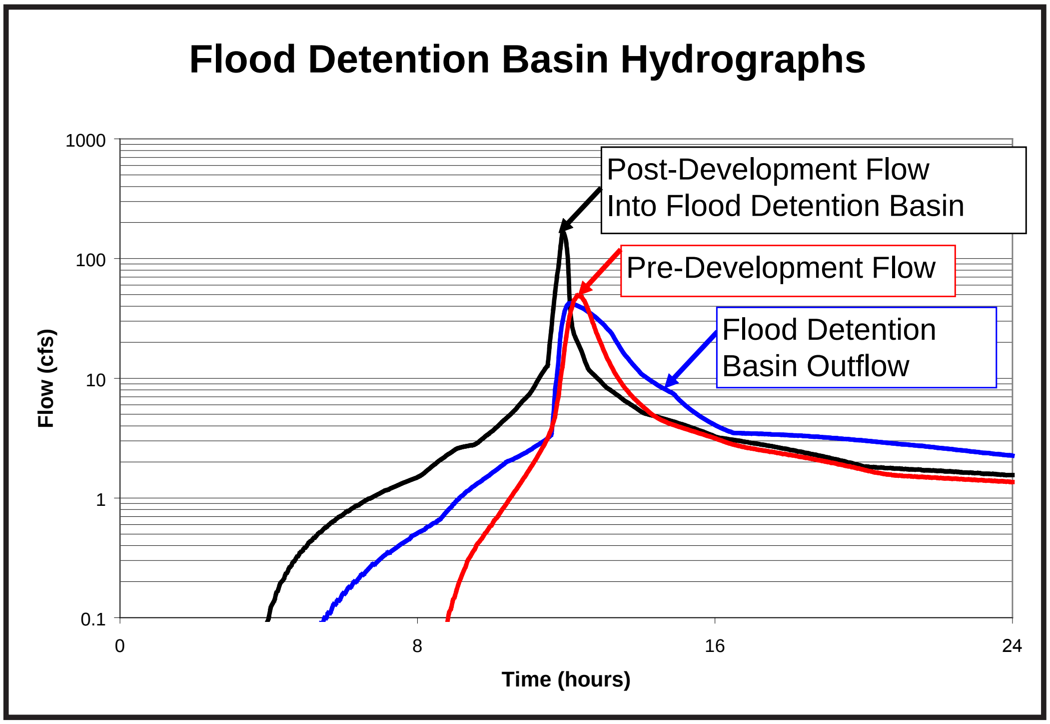


Figure 6:120 Dry pond for peak flow rate control only. Source: Metropolitan St. Louis Sewer District

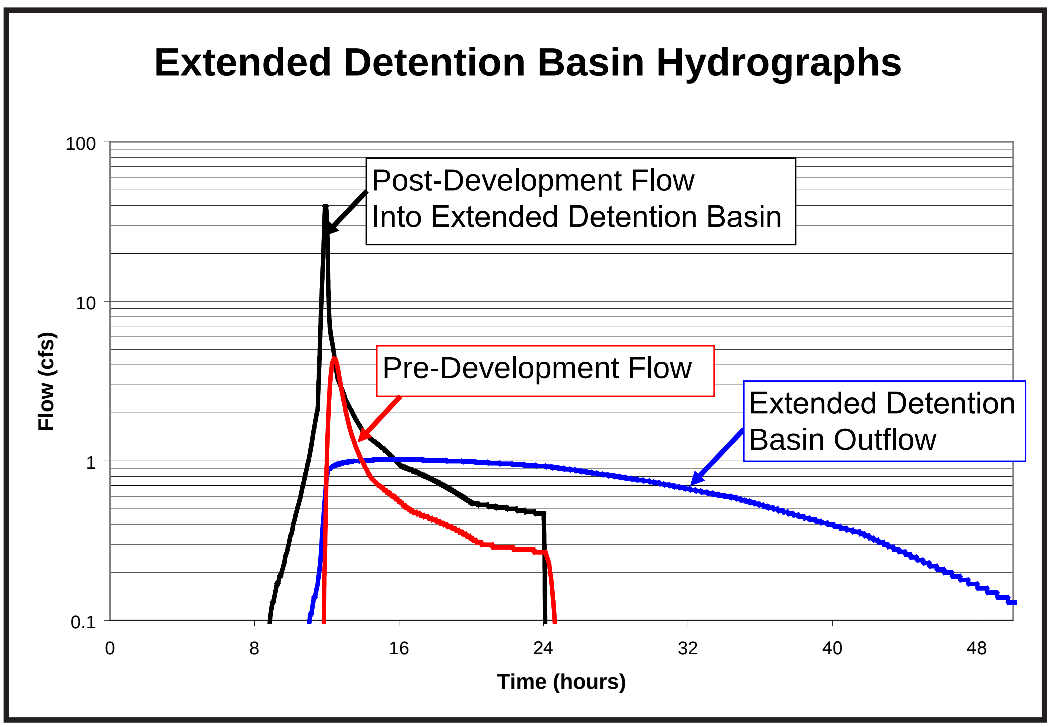


Figure 6.121 Extended detention dry pond for limited water quality control and for channel protection. Source: Metropolitan St. Louis Sewer District

Pollutant Removal

As noted previously, the historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff – essentially providing flood control. The dry pond is often used to reduce the peak flow rate from stormwater events and may temporarily minimize flooding downstream. Dry ponds designed to provide extended detention can benefit downstream water quality by protecting downstream channels from the frequent storm events that cause streambank erosion. However, when used to remove settleable pollutants, studies show some of the sediment and other pollutants are re-suspended and then discharged in recurring storm events

See Appendix C for the reference publication *Stormwater BMPs: Selection, Maintenance and Monitoring.* Additionally, dry ponds are not effective removers of soluble pollutants. As such, this practice seldom meets the overall quantity and quality objectives as a standalone practice.

If water quality treatment is a goal of dry detention basin design and construction, a wet or extended stormwater pond design should be incorporated. Dry ponds should be used in conjunction with other practices, as part of an overall treatment series; they should include enhancements such as a sediment forebay, extended storage, a micropool at the outlet, a long shape to minimize short-circuiting or a combination of these features. Effectiveness of dry ponds varies significantly depending on design, incorporation of companion water quality practices and maintenance.

Dry ponds with concrete conveyance channels or pilot swales should not be used, because they convey polluted stormwater directly to stream resources. See Figure 6:122.

Sediment clean-out should be tested for toxicants in compliance with current disposal requirements if commercial or industrial land uses contribute to the catchment, or if visual or olfactory indications of pollution are noticed

Figure 6.122 Detention basin with concrete conveyance channel. Source: Metropolitan St. Louis Sewer District

Costs Considerations

According to the Stormwater Manager's Resource Center, construction costs vary considerably, but the estimated costs of a typical extended dry detention basin may range from $41,600 per one acre-foot pond to $1,380,000 for a 100 acre-foot pond.

Costs associated with required space should be considered, especially when other practices such as bioswales and rain gardens can be worked into the natural landscape and meet water quality requirements.

Consideration should be given also to the economic impacts to neighboring properties. According to Emmerling-Dinovo, a 1995 study found that dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between three and 10 percent.
See the **Appendix C** reference for *Stormwater Detention Basins and Residential Locational Decisions* (1995.)

The estimated cost of maintenance is typically estimated at about three to five percent of the construction cost.

Recommended Minimum Requirements

Key considerations for constructing a dry pond is how big the pond should be, how the land should be graded, the location and size of the outlet structure and the elevation of drainage outlets. Typically, detention basins are designed through modeling to demonstrate specific design storm requirements that will be met. Deviation from the design can result in basin inefficiency at best, and intesifying of downstream flooding and erosion problems at worst.

Design should be in accordance with state-of-the-practice specifications aimed at achieving water quality criteria. When designed in conjunction with other appropriate runoff volume-reducing SCMs, detention basins may be reduced in size. Forebays may be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin and minimize erosion by inflow. The basin may also be planted with dense, low-growing native or adaptive vegetation that can withstand periods of inundation and drought, require no mowing and provide aesthetic and wildlife benefits.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, detention basins should be designed by a registered design engineer. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The detention basin should be built according to the planned grades and dimensions.

An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.

- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. Tree roots, rocks or boulders should be removed from the excavated area and disposed of in designated disposal areas.

- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.

- The final grading should include placement of planting soil.

- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.

- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is important for the swale to be stabilized before receiving upland flow.

Consult with the registered design engineer if any of the following occur:

- Seepage is encountered during construction.

- Variations in topography on-site indicate detention pond will not capture the drainage area intended.

- Design specifications for fill, pipe, seed/plant variety or seeding/planting dates cannot be met.

- Depression holds water long after the rain event, which does not allow vegetation to survive.

- Substitutions are required. Unapproved substitutions could lead to failure.

Construction Verification

Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures. If at final grade the basin storage volume is less than indicated on the plan (e.g., 10 percent less), orifice invert elevations vary more than 0.1' from plan, or if orifice size if different from plan, then the engineer should be consulted to determine if basin performance has been negatively impacted and if adjustments are needed.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design engineer and transferred to the person responsible for long-term operations and maintenance. Adequate training should be provided as well. Typical maintenance requirements include the following:

- Inspect the detention basin after each storm event greater than 1-inch in 24 hours. Remove trash and other debris from the basin. Collected sediment should be removed when 10 percent of the basin design volume has been filled, or 50 percent of the sediment forebay is filled.

- Periodically (e.g., annually) check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair upon discovery.

- Remove nuisance vegetation on the embankment as needed during the growing season (e.g., April to October).

- Remove rodents that burrow into the dam.

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar or pressure-injecting grout around the pipe.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation. Perform a soil test and amend the embankment as needed to establish vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate failed material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install proper outlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Check with the engineer to determine if the discharge can be lowered or if the basin can be filled. Re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properly water them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.

Wet Pond ("Retention")

Figure 6.123: Extended Wet Detention, Express Scripts Campus, Berkeley, MO.
Source: Metropolitan St. Louis Sewer District

Practice Description

Wet ponds are often referred to as stormwater ponds, retention ponds or wet detention ponds. A wet pond is designed to collect stormwater runoff in a permanent pool during storm events. The water stored in the pond is later displaced by new runoff. A wet pond can provide pollutant removal primarily through settling and microbial, plant and algal biological uptake. While wet ponds can provide water quality improvement, their role in runoff volume reduction is limited. Wet ponds are best used in combination with other stormwater control measures in an overall stormwater treatment train to achieve the desired affects of pollution control, storage and flow rate reduction. Many of the hydrograph principles that apply to dry ponds also apply to wet ponds. (See Dry Ponds.)

Variations of wet ponds include:

- Flow-Through (Wet) Pond (no extended detention, this pond has an essentially unrestricted spillway as its primary outlet, with its crest at the elevation of the permanent pool).
- Extended wet detention (extended detention storage is provided above the permanent pool).
- Water reuse pond (used primarily for irrigation.)

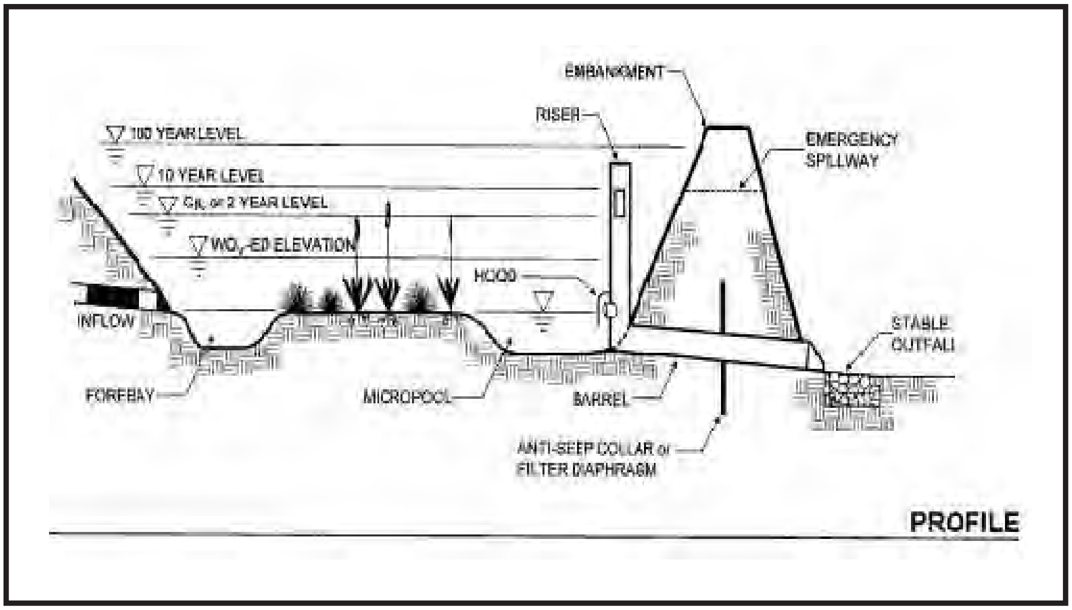


Figure 6:124 Wet Pond Cross Section Source: U.S. Environmental Protection Agency

The extended wet detention pond is a wet pond that works in tandem with a dry detention pond located above the permanent pool. During storm events, water is collected in the detention storage pond above and released over a period of 12 to 48 hours into the wet pond below.

Wet ponds can be used as a retrofit option in existing communities as modifications to existing detention facilities to enhance water quality treatment and downstream channel protection. If water quality, storage and reduced flow rate are the goals, wet ponds should be used in conjunction with other SCMs in an overall stormwater treatment train to achieve the best results. See Figure 6:102. At the very least, sediment and pollutant removal, as well as maintenance needs, can be enhanced through the use of multiple cells in succession.

Geese can often be attracted to wet ponds if the edges are mowed. However, unmowed native or adaptive vegetation around the edges will discourage geese and help to filter pollutants from stormwater runoff.

Additional Considerations

- Fluctuating water elevations make it difficult to establish plants.
- Use wet detention basins to treat runoff from stormwater hot spots, only if significantly separated from the groundwater table.
- Use of wet ponds is limited in dense urban areas due to the amount of space and drainage area required.
- Not appropriate for discharge to cold water resources, due to the potential for thermal pollution.
- Not appropriate for karst areas without significant consideration to leakage or sinkhole prevention.
- Safety is always a concern where permanent pools of water exist.

Cost Considerations
According to the Center for Watershed Protection, typical costs for wet detention ponds range from $17.50 to $35 per cubic meter ($0.50 to $1 per cubic foot) of storage area (CWP, 1998). The total cost for a pond includes permitting, design and construction and maintenance costs. Permitting costs may vary depending on state and local regulations. Typically, wet detention ponds are less costly to construct in undeveloped areas than to retrofit into developed areas. This is due to the cost of land and the difficulty in finding suitable sites in developed areas. The cost of relocating pre-existing utilities or structures is also a major concern in developed areas. Several studies have shown the construction cost of retrofitting a wet detention pond into a developed area may be 5 to 10 times the cost of constructing the same size pond in an undeveloped area. Annual inspection and maintenance costs can generally be estimated at three to five percent of the construction costs.

Recommended Minimum Requirements
The design should reflect the design criteria that could include the following key elements:

- An adequate contributing drainage area, typically more than 10 acres. A water balance assessment should be provided for smaller drainage areas.
- Natural high groundwater table.
- Maintenance of a permanent water surface.
- A length to width ratio of 2:1, or irregular shapes that maximize flow path between inlet and outlet points.
- An aquatic bench with diverse vegetation around the perimeter.
- Relatively impermeable soils, or lining of the pond bottom.
- A forebay for coarse sediment and trash collection.
- Outfall protection to prevent erosion.
- Access for maintenance.

The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation. In Missouri, dams with a height of 35 feet or greater require approval from the Missouri Department of Natural Resources' Dam Safety Program. (See Chapter 1 for information about permits and regulations.)

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction
Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, the wet pond should be designed by a registered design engineer. Typically, this SCM is comprised of a forebay, an embankment to create the basin(s), an outlet structure, a spillway for overflows and safe access.

Plans and specifications should be reviewed by the site superintendent and field personnel and followed closely throughout the construction process. The basin should be built according to the planned grades and dimensions. An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.
- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. All tree roots, rocks, or boulders should be removed from the excavated area.
- Rough grading of the basin should be completed carefully to ensure compaction of the bottom of the basin.
- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.
- The final grading should include placement of planting soil.
- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.
- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls.

Construction Verification

Construction verification needs for dry and wet ponds are similar. Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design professional. After construction is complete and the detention basin is operational, operations and maintenance of each device is performed by the personnel identified in the operations and maintenance manual. Typical maintenance requirements include the following:

- Periodically check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Clean and remove trash and vegetative debris from inlet and outlet structures, mow side slopes as needed.
- Semi-annual inspection for invasive vegetation.
- Annual inspection to monitor damage, hydrocarbon build-up, sediment accumulation and debris in inlet and outlet devices.
- Repair erosion and remove excess sediment from forebay as needed.
- Manage and harvest wetland plants annually.
- Renovate the facility when pool volume has been reduced significantly or when the pond becomes eutrophic (excessive in nutrients, resulting in algal blooms and poor water quality.)

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate dislocated material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install proper outlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Relocate basin to more accessible area or improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Lower the discharge to release storm flows and re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properly water them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.

Stormwater Wetlands (Constructed Wetlands)

Practice Description

Stormwater wetlands are constructed wetland systems that temporarily store stormwater runoff in shallow pools supportive of wetland plants. They are constructed primarily for the purposes of water quality treatment and flood control; primarily flow attenuation and some runoff volume reduction. Stormwater wetlands are constructed for maximum removal of stormwater pollutants through microbial breakdown of pollutants, pollutant uptake by plants, settling and absorption. Stormwater wetlands typically have less biodiversity than natural wetlands in terms of plant and animal life. Natural wetlands are to be protected and should never be used for stormwater management, because their function is critical to watershed health. See Chapter 1 for regulations and permit requirements.

Constructed wetlands are a widely applicable stormwater management practice in areas where sufficient land is available. There should be significant separation from groundwater if constructed wetlands accept runoff from stormwater hot spots. If the areas are designed to encourage wildlife use, the design must ensure pollutants in stormwater runoff do not affect organisms living in or near the wetland. When retrofitting a watershed with SCMs, stormwater wetlands can provide both educational and habitat value.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative descriptions of plant species native to Missouri and the Midwest region.

Stormwater wetland designs vary in the relative amount of shallow water, deep water and dry storage above the wetland. The five general design variations include:

- Shallow marsh system.
- Pond/wetland system.
- Extended detention wetland.
- Submerged gravel wetland.
- Pocket Wetland.

Of the wetland types, the extended detention wetland or pond/wetland system may be most common in urban areas with adequate land. Where space is more limited or retrofits are needed, a submerged gravel wetland might be considered. Pocket ponds are only an option where groundwater is available to help charge the pond; not a typical setting in urban environments. The shallow marsh system requires the largest area of all wetland types.

Shallow Marsh System

A shallow marsh system includes a combination of pools (low marsh) and vegetated hummocks (high marsh), plus a micropool at the outlet. Pools wind through the high marsh in meandering pathways to extend the amount of time stormwater is held and treated in the system and to increase contact between stormwater and vegetation. These systems are generally shallow and therefore receive no groundwater inputs, so they typically require large drainage areas (e.g., >25 acres) to contribute the necessary water volume to the system.

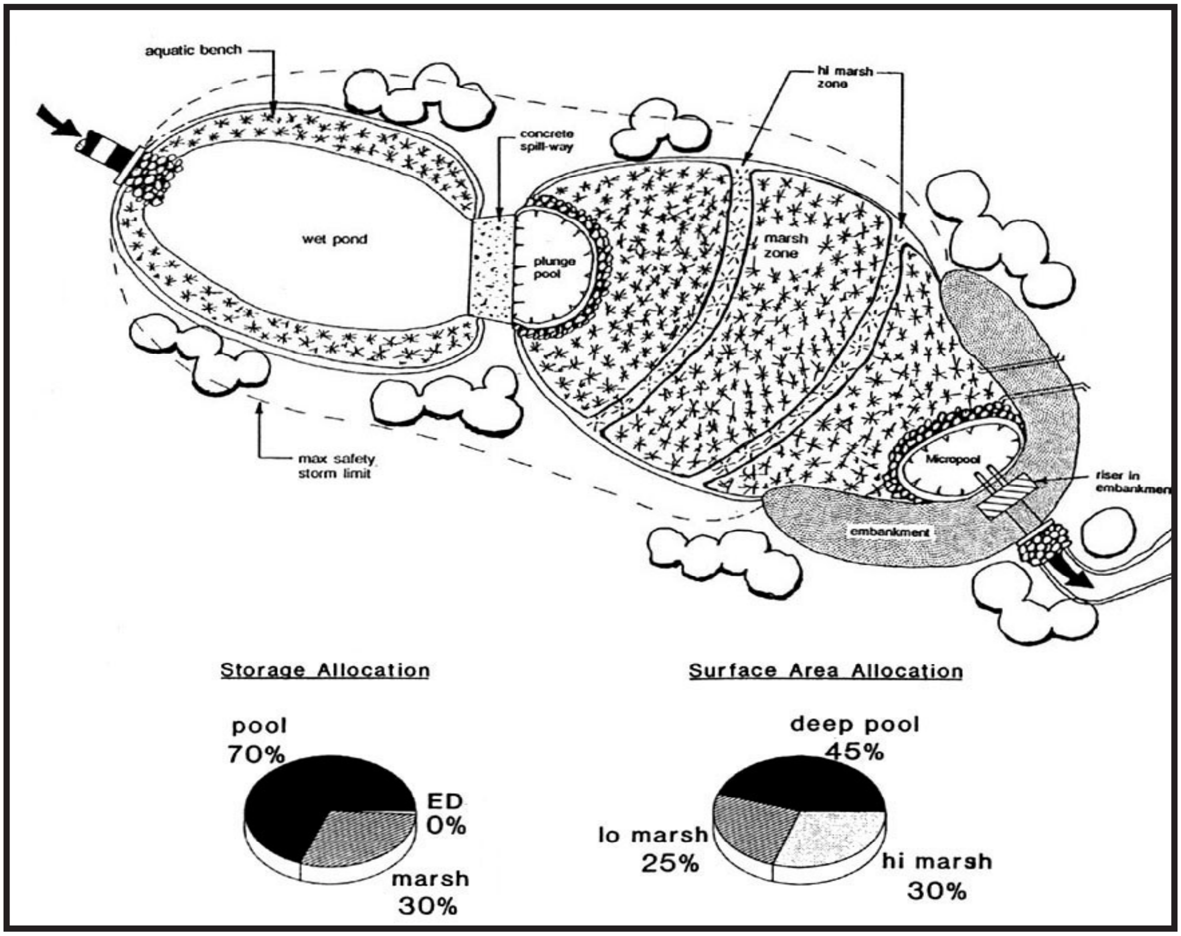


Figure 6.125 Pond/Wetland System Source: Center for Watershed Protection

Extended Detention Wetland

An extended detention wetland is much like a shallow marsh system, but it includes the addition of a forebay and safety bench.

An extended detention wetland includes features to enhance storage, downstream channel protection and pollution reduction. It has sufficient volume to temporarily detain runoff during storm events and hold a permanent pool of fairly shallow depth. Biological and chemical activity in the pond plays an important role in pollutant uptake, particularly of nutrients. Flow through the root systems allows vegetation to remove nutrients and dissolved pollutants from stormwater. When an extended detention wetland is sized, designers need to consider the storage volumes provided. Typically, a significant portion (e.g., 50 percent) of the water quality volume (the volume of rainfall produced by the 90th to 95th percentile storm that occurs in 24 hours) is provided in the micropool(s). The detention volume above the pool is designed to provided extended detention of the remaining portion of the water quality volume, channel protection volume and flood protection volume.

Because the ponding depths are typically shallow to be effective, extended detention wetlands require a large amount of surface area to obtain sufficient volume. Because they function best in larger drainge areas, they may be a good choice to treat runoff from large industrial and commercial project sites that have sufficient space for their construction. These constructed wetlands can also provide aesthetic/recreational value and wildlife habitat.

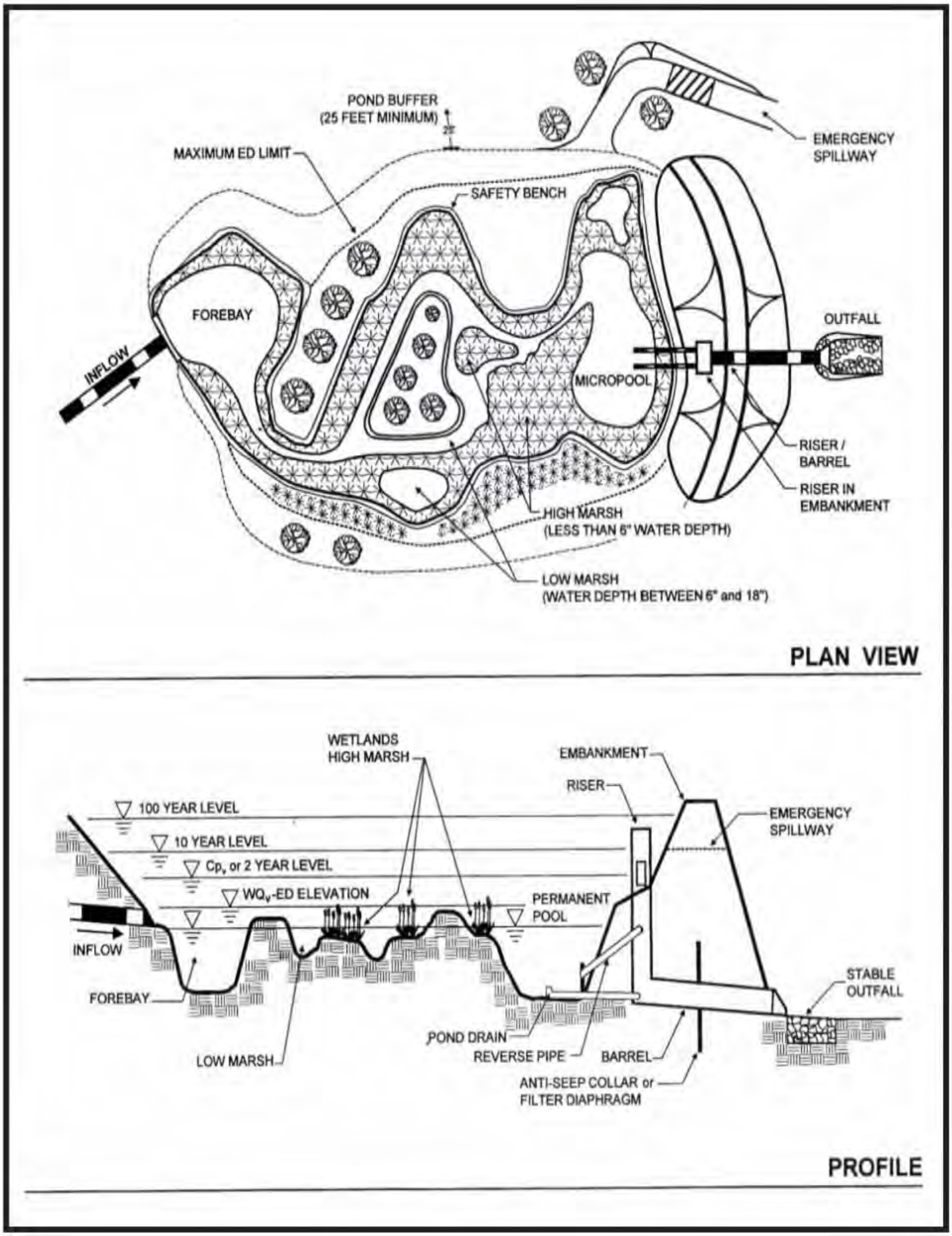


Figure 6.126: Constructed Extended Detention Wetland. Source: Center for Watershed Protection

Figure 6.127: Extended Detention Wetland in a Residential Development. Dover, Delaware. Source: Kevin Magerr, PE, CPESC, CPSWQ.

The successful design, installation and function of constructed wetlands depends on the hydrology, underlying soils, planting soil, size and volume, vegetation, configuration, and maintenance access. Large areas are necessary for application of this SCM; the contributing drainage area should be at least 10 acres. The area for a wetland is generally 3 to 5 percent of its drainage area but it should be sized to treat the water quality volume and if necessary, mitigate the peaks of larger runoff events. A wetland must be able to receive and retain enough rain, runoff and groundwater to maintain vegetation. Even with a large drainage area, a constant source of inflow can improve the biological health of a wetland.

Submerged Gravel Wetland

A submerged gravel wetland is a practice that can be used in retrofit situations draining less than five acres. In the submerged gravel wetland, the system is designed for runoff to flow through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the media (e.g., gravel) and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave

Figure 6.128: Submerged Gravel Wetland. Source: Center for Watershed Protection, Copyright 2000.

much like wet ponds (with differences in grading and landscaping), gravel-based wetlands are more similar to filtering systems. Design considerations should be given to potential clogging and odor problems. Submerged gravel wetlands are commonly associated with wastewater treatment applications, but have been adapted to stormwater treatment application.

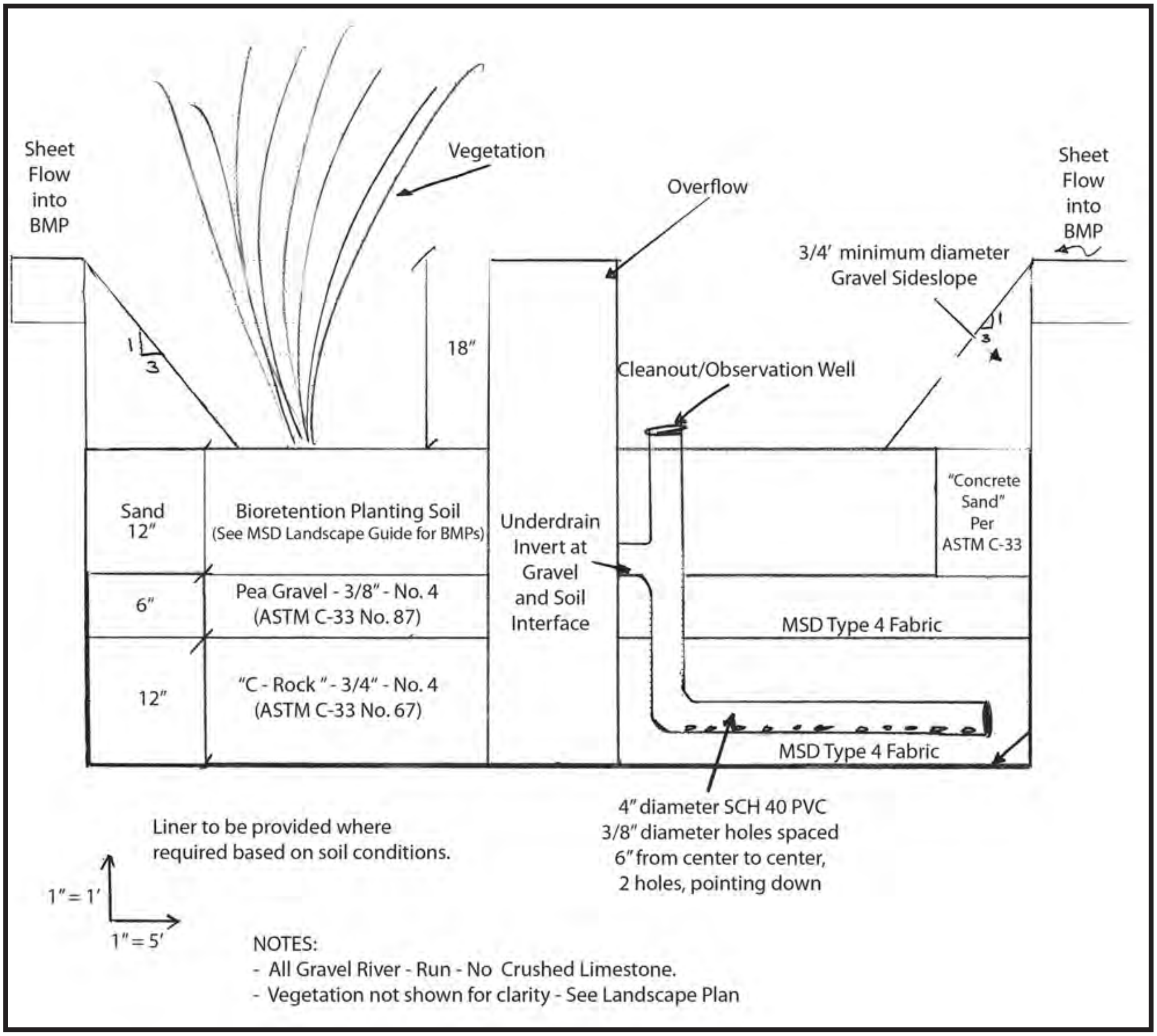


Figure 6.129. Submerged Gravel Wetland. Source: Metropolitan St. Louis Sewer District

Pond/Wetland System

A pond/wetland system consists of multiple cells with at least one wet pond followed by at least one shallow marsh and draining areas less than 25 acres. This practice can save space when compared to a shallow marsh system which requires a greater area of land to address storage.

Pollutant Removal

Wetlands can be designed to primarily remove total suspended solids, oils and greases, fecal coliform and biochemical oxygen demand. They can also be designed to remove some levels of Total phosphorus, nitrogen, heavy metals and floatables.

The following in formation on pollutant removal comes from EPA's *Stormwater Wetland* fact sheet. (See reference in Appendix C.) Wetlands are among the most effective stormwater management practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are particularly effective at removing nitrate and bacteria. Table 6.18 provides pollutant removal data derived from the Center for Watershed Protections's National Pollutant Removal Database for Stormwater Treatment Practices (Winer, 2000).

Table 6.18. Typical Pollutant Removal Rates of Wetlands (%) (Winer, 2000.)

Pollutant	Stormwater Treatment Practice Design Variation			
	Shallow Marsh	ED Wetland1	Pond/Wetland System	Submerged Gravel Wetland1
Suspended Solids	83±51	69	71±35	83
Total Phosphorus	43±40	39	56±35	64
Total Nitrogen	26±49	56	19±29	19
Nitrogen Oxide	73±49	35	40±68	81
Metals	36-85	(80)-63	0-57	21-83
Bacteria	761	NA	NA	78

[1] Data based on fewer than five data points

The effectiveness of wetlands varies considerably, but many believe proper design and maintenance help to improve their performance. The siting and design criteria presented in the EPA's *Stormwater Wetland* fact sheet reflect the best current information and experience to improve the performance of wetlands. A joint project of the American Society of Civil Engineers and the EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice database is a compilation of stormwater practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. [More information is available at the International BMP Database located at www.bmpdatabase.org.]

Additional Considerations

The following information about wetland limitations is adapted from EPA's *Stormwater Wetland* fact sheet. See reference in Appendix C. Some features of stormwater wetlands that might make a design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on some sites.
- Improperly designed wetlands might become a breeding area for mosquitoes.

- Wetlands require careful design and planning to ensure wetland plants are sustained after the practice is in place.
- It is possible stormwater wetlands may release nutrients during the non-growing season.
- Designers need to ensure wetlands do not negatively impact natural wetlands, forest or groundwater quality.

Cost Considerations

The following information comes from EPA's *Stormwater Wetland* fact sheet from their menu of stormwater BMPs. See Appendix C. Wetlands are relatively inexpensive stormwater practices to construct, not counting the cost of land. Construction cost data for wetlands are rare, but one simplifying assumption is that they are typically about 25 percent more expensive than stormwater ponds of an equivalent volume. Using this assumption, an equation developed by Brown and Schueler (1997) to estimate the cost of wet ponds can be modified to estimate the cost of stormwater wetlands using the equation:

C = 30.6V0.705 where: C = Construction, design and permitting cost.
V = Wetland volume needed to control the 10-year storm (ft3).

Using this equation, typical construction costs are the following:

- $57,100 for a 1 acre-foot facility.
- $289,000 for a 10 acre-foot facility.
- $1,470,000 for a 100 acre-foot facility.

Wetlands consume about 3 to 5 percent of the land that drains to them, which is relatively high compared with other stormwater management practices.

For wetlands, the annual cost of routine maintenance is typically estimated at about 3 percent to 5 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Wetlands are long-lived facilities (typically longer than 20 years). Thus, the initial investment into these systems may be spread over a relatively long time period.

Recommended Minimum Requirements

Underlying soils should be identified and tested. Hydrologic soil groups 'C' and 'D' are suitable without modification but 'A' and 'B' soils may require the addition of clay or other impermeable material to line the facility. Soil permeability should be tested and calculations should demonstrate the wetland will not dry out. Organic soils should be used to establish vegetation. Vegetation is an integral part of a wetland and plays a role in reducing flow velocities, promoting settling, providing growth surfaces for beneficial microbes, and taking up pollutants. Vegetation types such as emergent, low marsh, high marsh, and buffer plants should be installed in appropriate zones for the various areas in a wetland. To allow maintenance activities, a stable and permanent access should be provided to the forebay, outlet and embankment areas. Also, an understanding of seasonal groundwater levels is critical.

Medium-fine textured soils (such as loams and silt loams) are best to establish vegetation, retain surface water while permitting groundwater recharge and capture pollutants. For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region.

In karst (e.g., limestone) topography, wetlands should be designed with an impermeable liner to prevent groundwater contamination or sinkhole formation, and to help maintain the permanent pool. The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation.

The wetland should be designed by a registered design engineer as part of the overall site design for long-term water quality. Design considerations include:

- Water quality goals, flood management goals and performance needs (including appropriate variation for new growth, redevelopment or restoration).
- Proximity to karst and groundwater and other limitations.
- Wetland to watershed ratio and other sizing criteria.
- Topography, soils, sediment forebays.
- Buffers to separate wetland from the surrounding area.
- Above ground berms or high marsh wedges placed perpendicular to the flow path to increase dry weather flow paths within the wetland.
- Placement of the outlet with clog-prevention micropool.
- Maintenance access.
- Long-term operation, Inspection and maintenance.
- Construction sequencing.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process. The construction sequence may include:

- Separating the wetland area from the contributing drainage area and initiating an appropriate erosion and sediment control plan.
- Clearing the area to be excavated of all existing vegetation. Removing tree roots, rocks and boulders. Filling all stump holes and crevices with impermeable materials.
- Excavating the bottom of the constructed wetland to the desired elevation, as indicated in the plans.
- Grading the embankments.
- Installing inlet and outlet control structures.
- Final grading and compacting of subsoil.
- Applying and grading the planting soils. It is critical the final grading match the design

because aquatic plants are sensitive to the depth of water.

- Installing geotextiles and other permanent erosion control measures.

- Seeding, planting and mulching according to the plans.

Maintenance and Inspection

Routine harvesting of vegetation has been documented to increase nutrient removal capacity of a constructed wetland and prevent the export of these constituents. Typical maintenance includes:

- Inspect the facility semiannually for burrows, sediment accumulation, structural integrity of the outlet and litter accumulation. The banks of the wetland should be inspected and areas of erosion repaired upon discovery. Sediments should be removed if they are within 18 inches of an outlet structure.

- Maintain emergent and perimeter shoreline vegetation. Site and road access are important to facilitate monitoring and maintenance.

- Remove nuisance vegetation or animals, if present.

- Harvest vegetation as prescribed in the specifications. Frequencies will vary. Vegetation is typically not collected during the growing season.

- The side slopes should be maintained at a slope that does not exceed 4:1 (H:V). Slopes showing excessive erosion may require erosion control and safety measures.

Sediments that accumulate in constructed wetlands may require special disposal. If there is any uncertainty about the sediment characteristics, the Missouri Department of Natural Resources should be consulted and department disposal recommendations should be followed.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Common Problems and Solutions

Problem	Solution
Erosion of slopes; caused by inadequate vegetation or improper grading and sloping	Repair damage and establish suitable grade or vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil	Excavate failed material and replace with properly compacted suitable soil.
Insufficient vegetation due to improper zones or depths of ponding.	Lower the discharge to release storm flows and re-vegetate damaged areas.
Stormwater released from pond or basin too rapidly; caused by discharge	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Plant selection should include native species tolerant of both wet and dry cycles. Deep rooted perennials increase the rate of infiltration.

Infiltration Basin

Figure 6.130: Infiltration Basin. Source: University of Wisconsin Extension

Practice Description

Infiltration basins are earthen structures that capture stormwater in a shallow pool and infiltrate runoff into the ground over a period of 72 hours. Infiltration basins differ from detention basins in that they do not have an outlet. Typically, an infiltration basin includes an inlet, sediment forebay, level spreader, spillway, backup underdrain, an emergency spillway and a stilling basin. Vegetation is used within the basin to improve the permeability of soils and reduce the potential for erosion. Some communities have observed it is difficult to maintain desired turf grass. Alternative plant materials should be considered.

An infiltration basin should be designed by a registered design engineer as part of the overall site design for long-term water quality. Design considerations include:

- Infiltration basins should be restricted to areas where groundwater contamination, site feasibility, soil permeability and clogging at the site are not concerns.
- The contributing drainage area to a basin should not produce high concentrations of sediments and should be less than 2 acres.
- This SCM works well toward the end of a treatment train when there are sufficient pretreatment steps to reduce the sediment loads.
- Because these basins are designed for maximum infiltration, they should not be constructed in regions of karst topography, due to concerns of sinkhole formation and groundwater contamination.
- These basins should never be constructed in stormwater hot spots. Stormwater hotspots are areas that produce higher concentrations of pollutants than what is normally found in urban runoff.

Recommended Minimum Requirements

Infiltration basins may be incorporated into new development or used to retrofit existing lawns and open spaces. Site selection for an infiltration basin should be based on soil infiltration, depth to water table, setbacks, loading rates and existing vegetation. Soil investigation and infiltration testing provides essential information for a proper design. Basins should be located 150 feet away from drinking water wells to prevent possible contamination and these basins should not be located adjacent to building foundations; they should be placed at least 10 feet down-gradient and 100 feet up-gradient from foundations. Infiltration basins should not be used in areas where groundwater is close to the surface.

After locating the infiltration basin, the designer should prepare plans sufficient for the structure to retain 1-foot freeboard during the average 100-year peak runoff. Use of a backup underdrain (capped or closed with a valve during normal operation) may be considered if there is concern the basin may not drain. The underdrain may need to be used later when surface soils become clogged and need to be amended or replaced. Inlets to the basin should have erosion protection. The slope of the infiltration basin base should be less than 1 percent to ensure even water distribution and infiltration. The berms surrounding the basin should be constructed of compacted earth with a minimum top width of 2-feet and side slopes not steeper than 3:1 (H:V). The length to width ratio of the basin should be 3:1 or greater. The designer should review local requirements for site grading, drainage structures, erosion and sediment control and planting.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to the start of construction, plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The wetland should be built according to the planned grades and dimensions.

Site Preparation

The infiltration basin area should be protected from compaction prior to installation.
Proper erosion and sediment control measures should be installed and maintained during construction to prevent site runoff from entering the infiltration basin.

Grading and Installation

It is preferable to locate infiltration basins with consideration of existing topography to minimize excavation. If necessary, excavate the basin bottom to an uncompacted sub-grade free from rocks and debris. It is important to avoid compaction of the sub-grade. After the bottom and side slopes have been established, the outlet control structures should be installed. Finally, the topsoil should be vegetated and stabilized. Erosion and sediment control measures must remain in place and maintained until the site is stabilized.

Vegetation

The selection should include native and adaptive species tolerant of both wet and dry cycles. Deep rooted perennials are encouraged to increase the rate of infiltration.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region.

Construction Verification

Measure the finished grades and configuration and compare against the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Twice each year, the basin and inlets should be inspected for accumulation of trash, sediment and erosion. They should also be checked for stabilization and vegetation quality. Inspections should also occur after significant runoff events and drainage times should be observed to match the design intention. The vegetation along the surface should be maintained and any bare spots identified during inspections should be revegetated. Depending on the vegetative cover species, an infiltration basin may be carefully mowed as needed but care should be taken to avoid excessive compaction by mowers (i.e. mowing should not occur when the ground is saturated).

Common Problems and Solutions

Problem	Solution
Potential failure due to improper siting, design and lack of maintenance.	Incorporate pretreatment if contributing drainage area is providing too much sediment.
Compaction during mowing.	Rototill existing soil when in friable condition and reseed.
Drawdown time is longer than 72 hours.	Rototill existing soil when in friable condition and reseed.
Unsuccessful vegetation establishment.	Recheck soil conditions for tilth and for conditions suitable for plant growth. Choose plant species that prefer the site conditions and are appropriate for the plant zone. Reset plants during an appropriate planting season. Reapply mulch.
Unsuccessful vegetation establishment.	Plant selection should include native species tolerant of both wet and dry cycles. Deep rooted perennials increase the rate of infiltration.

Infiltration Trench

Practice Description

Figure 6.131: Infiltration trench with geotextile. Source: Southeast Michigan Council of Governments/Michigan Department of Natural Resources

Infiltration trenches are excavated trenches filled with granular material. These trenches are primarily used to slow stormwater runoff rates and promote infiltration of runoff into the ground. The most effective period of an infiltration trench is during the first flush of a runoff event when most of the runoff and pollutants are captured. Infiltration trenches remove suspended solids, bacteria, organics, soluble metals and nutrients through mechanisms of filtration, absorption and microbial decomposition. This SCM may be used in combination with another SCM such as a detention basin to increase the control of peak flows, or in combination with other SCMs as part of an overall treatment train.

Infiltration trenches have select applications and their use is restricted by concerns due to common site factors, such as potential groundwater contamination, soils and clogging. In regions of karst (i.e., limestone) topography, infiltration trenches may not be appropriate due to concerns of sinkhole formation and groundwater contamination. Infiltration trenches can sometimes be applied in the ultra-urban environment but should not be located adjacent to stormwater hot spots. Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure and poor infiltration capacity of soils.

Figure 6.132: Biolfiltration Infiltration Trench, Cumberland County, PA.
Source: Pennsylvania Department of Environmental Protection

Recommended Minimum Requirements

This SCM should be designed by a registered design engineer as part of the overall site design for long-term water quality. Site selection for an infiltration trench should be based on soil infiltration, depth to water table, setbacks, loading rates and existing vegetation. Soil investigation and infiltration testing is a minimum requirement to inform design. Trenches should be located 150 feet away from drinking water wells to prevent possible contamination and should not be located adjacent to building foundations; they should be placed at least 10 feet down-gradient and 100 feet up-gradient from foundations. Infiltration trenches should not be used in areas where groundwater is close to the surface. This SCM may have either a grassed or gravel surface and may be located adjacent to roadways or impervious paved areas.

The width and depth of an infiltration trench may vary. The depth of stone, however, should be limited to six feet. The designer should review local requirements for site grading, drainage structures, erosion and sediment control and invasive or nuisance vegetation.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

Site Preparation and Installation

Protecting the infiltration trench area from compaction prior to installation is critical. If possible, the infiltration trench should be constructed during the later phases of site construction to prevent sedimentation or damage from construction activity. Erosion and sediment control measures need to be installed prior to construction and maintained during the course of construction.
A construction sequence might include:

- Install and maintain erosion and sediment control measures.
- Excavate the infiltration trench bottom to develop a uniform, level, uncompacted subgrade free from rocks and debris. It is critical to not compact the subgrade.
- Place nonwoven geotextile fabrics along the bottom and sides of the trench. (Clogging tendencies of the fabric should be taken into consideration during design.) Nonwoven geotextile fabric should be rolled out to overlap by a minimum of 16-inches within the trench. Excess geotextile should be folded and secured during stone placement.
- Install upstream and downstream cleanouts and control structures.
- Install continuously perforated pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
- If topsoil is to be placed on top of the trench, a geotextile should be folded and secured over the infiltration trench and the area shall be seeded and stabilized.
- Within 24 hours, remove any sediment that enters inlets during construction.

Construction Verification

Check the finished grades and configuration of all elements. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Pretreatment devices, catch basins and inlets should be inspected for sediment buildup and cleaned at least twice each year. Observation wells should be inspected following three days of dry weather because failure to percolate will indicate clogging. If vegetation is planted on the surface of the infiltration trench, it should be maintained in good condition, and any bare spots should be revegetated as soon as possible. A vehicle should not be parked or driven over the surface of an infiltration trench. Care should be taken to avoid compaction by mowers if the trench has surface vegetation. Upon failure, the trench should be rehabilitated and trench walls should be excavated to expose clean soil.

Common Problems and Solutions

Problem	Solution
Potential failure due to improper siting, design and lack of maintenance.	Incorporate pretreatment if the contributing drainage area is providing too much sediment.
Sediment accumulation at catch basins or inlets.	Remove accumulated sediment through standard maintenance procedures.
Practice not functioning well.	Infiltration trenches do not work well in clay soils. Practice should be initially designed with amended soils, or a different practice should be chosen.

Porous Pavement and Pervious Pavers

Figure 6.133: Porous Asphalt Alley, St. Louis, MO. Source: Metropolitan St. Louis Sewer District

Practice Description

Porous pavement and a variety of pervious pavers provide a permeable surface that can be used to replace traditional pavement areas. Several systems may be used including pervious concrete and porous asphalt, precast concrete grids, modular unit pavers, geowebs and other manufactured pavement systems.

Porous pavement is usually built with an underlying stone reservoir that temporarily stores surface runoff before it infiltrates into the subsoil. Porous asphalt and pervious concrete looks very similar to traditional pavement, however, porous pavement contains little or no “fine” materials. Instead, it contains voids that allow infiltration through the pavement. Porous asphalt consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to allow water movement. Pervious concrete typically consists of specially formulated mixtures of Portland cement, open-graded coarse aggregate and water. Pervious concrete has enough void space to allow rapid percolation of stormwater through the pavement. Moderate traffic zones are ideal locations for the application of porous pavement options.

See Appendix D for reference to EPA Menu of BMPs, specifically post-construction fact sheets named *Permeable Interlocking Concrete Pavement, Pervious Concrete Pavement and Porous Asphalt Pavement*.

Additional Considerations

- In some areas, such as truck loading docks and areas of high commercial traffic, porous pavement is inappropriate and presents maintenance issues.
- Since porous pavement is an infiltration practice, it should not be applied at stormwater hot spots (areas of unusually high pollution runoff) due to the potential for groundwater contamination.
- Porous pavement is not an option for drinking water recharge areas, due to contamination potential.

Pervious pavers and turf blocks can be used as a porous pavement option. Options include pre-cast concrete grids with void areas for grass, modular unit pavers installed with pervious material in the gaps, and geowebs designed for soil reinforcement. Alternative pavers can be used to replace historical pavement options in parking lots, driveways and walkways. The traffic volume, weight and frequency limit application. Pervious pavement and turf blocks are often applied to overflow parking areas and in residential settings. They can be used in combination with other stormwater SCMs.

Recommended Minimum Requirements

This SCM should be designed by a registered design engineer as part of the overall site design for long-term water quality.

Porous pavement should be used for low to medium traffic areas, for parking lanes and parking lots. Porous pavements should be placed on flat ground, but the slopes of the site draining to the practice should not be steeper than 15 percent. Soils need to have a permeability of at least 0.5 inches per hour. An alternative design for soils with low porosity would be the installation of a discharge pipe from a storage area beneath the pervious pavement that drains to the traditional storm sewer system. To reduce the risk of contamination, design should provide significant separation of 2- to 5-feet from the bottom of the porous pavement stone reservoir and the seasonally high groundwater table. Additionally, porous pavement installations should not be installed within the vicinity of drinking water wells. The bottom of the stone reservoir should be flat, so that runoff can infiltrate through the entire surface.

Pervious pavers and turf blocks should be situated to accept smaller contributing drainage areas, usually less than 5 acres, with relatively high impervious cover. The designer should evaluate the durability and maintenance cost of alternate pavement options. Soil types will affect infiltration rates and clay soils will substantially limit infiltration on a site. If groundwater pollution is a concern, permeable pavers should not be used.

The designer should always review local requirements for site grading, drainage structures and erosion and sediment control.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information on regulations and permit requirements.

Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process.

Due to the nature of construction sites, pervious pavement and other infiltration measures should be installed toward the end of the construction period. Infiltration beds under pervious pavement may be used as temporary sediment basins or traps. After the site is stabilized and sediment storage is no longer required, the bed may be excavated to its final grade and the pervious pavement system can be reinstalled as directed in the contract documents. The following sequence of construction steps provides an example:

- The existing subgrade under the bed areas should not be compacted or subject to excessive construction equipment prior to geotextile and stone bed placement.
- Where the erosion of the subgrade has caused accumulation of fine materials or surface ponding, this material shall be removed with light equipment and the underlying soils should be scarified to a minimum depth of 6-inches. All fine grading should be done by hand and the bottom of the bed should be at a level grade to prevent ponding.
- Earthen berms between infiltration beds should be left in place during excavation. These berms do not require compaction if proven stable during construction.
- If an underdrain system is designed, it should be installed before the subgrade for the infiltration bed is prepared.
- Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation. Geotextile should be placed in accordance with manufacturer's recommendations and specifications. Geotextile fabric should overlap a minimum of 16-inches and should be secured at least 4-feet outside of the bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils adjacent to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back.
- Clean, uniformly washed graded aggregate should be placed into the prepared bed in 8-inch lifts. Each layer should be lightly compacted, with the construction equipment kept off the bed bottom as much as possible. After bed aggregate is installed to the desired grade, a 1- inch layer of base course such as AASHTO M-43 #57 aggregate could be installed uniformly over the surface in order to provide an even surface for paving.
- The pervious pavement materials (pervious concrete or asphalt) or pavers should be installed in accordance with current standards.

Construction Verification
The full permeability of the pavement surface should be tested by applying clean water at a rate of at least 5 gallons per minute over the surface. All applied water should infiltrate directly without puddle formation or surface runoff.

Maintenance and Inspection
Pervious Pavement
The primary goal of pervious pavement maintenance is to prevent the pavement surface and underlying infiltration bed from clogging. Pores can become clogged when fine particles deposit on the surface from vehicles, the atmosphere and runoff from adjacent land surfaces. Clogging increases with age and use. Permeability can be maintained through vacuum sweeping using equipment, frequency schedules and precautions defined in the operation and maintenance plan. In areas where extreme clogging has occurred, half inch holes can be drilled through the pavement surface every few feet or so to allow stormwater to drain to the aggregate base. All inlet structures draining to the infiltration area should be cleaned out at least annually. Additionally, the surface should be inspected for deterioration annually. If not easily noticed, pervious pavement areas should be identified with signage to aid inspection.

Planted areas adjacent to a pervious pavement area should be well maintained to prevent soil washout onto the pavement. Any bare spots or eroded areas should be revegetated upon discovery. Planted areas should be inspected on a semiannual basis.

Trucks and other heavy vehicles should be prevented from tracking or spilling dirt on the pavement. All construction or hazardous materials carriers should be prohibited from driving on pervious pavement.

Winter maintenance for a pervious parking lot is typically less intensive because pervious pavement has superior snow melting characteristics. The underlying stone beds absorb and retain heat so freezing rain and snow melt faster on pervious pavement. Abrasives such as sand should not be applied on or adjacent to the pervious pavement. Snow plowing is acceptable, provided it is completed carefully, with the blade set slightly higher than usual (about 1-inch). Salt is acceptable though nontoxic, organic deicers, applied as blended magnesium chloride-based liquid products or as pretreated salt, are preferable.

Potholes are unlikely although settling may occur. For damaged areas less than 50 square feet, a pothole or failure should be patched by any means suitable with standard pavement or a pervious mix. If the repair area is greater than 50 square feet, the design engineer should be consulted. The pavement surface should never be seal coated.

Pavers

Maintenance of paver systems will vary greatly. The owner and engineer should refer to the manufacturer's recommendations. The turf installed in the pervious voids should be maintained with minimal fertilizer. The application of deicing chemicals should be limited.

Common Problems and Solutions

Problem	Solution
Decreased infiltration capacity.	Porous pavements are best maintained by vacuuming.
Pothole damage in an areas less than 50 square feet.	A pothole or failure should be patched by any means suitable with standard pavement or a pervious mix.
Sediment accumulation from adjacent landscaped areas.	Planted areas should be well maintained to prevent soil washout onto the pavement. Any bare spots or eroded areas should be revegetated upon discovery.

Sand Filters

Figure 6.134: Perimeter Sand Filter. Source: Center for Watershed Protection

Practice Description

Sand filter systems may be constructed on the surface or underground in vaults for large sites. Perimeter filters with a two-chamber concrete vault can be applied along the perimeter of a parking lot. Pocket sand filters are used at small sites and combine a sediment basin or filter strip preceding a vegetated depression full of sand. Sand filters are associated with high removal rates for filterable pollutants such as sediment, organic solids (i.e., biological oxygen demand), and fecal coliform bacteria. These filters are not efficient in removing soluble pollutants such as metals and nutrients.

Because sand filters provide treatment (pollutant capture), they are preferred to infiltration practices when contamination of groundwater is a concern, such as in areas where underlying soils cannot treat runoff or where groundwater tables are high. Because flow-through is fairly rapid, sand filters are not significant volume reducing SCMs.

A typical sand filter system consists of two or three chambers: a sedimentation basin to remove floatable materials and heavy sediments, a filtration basin where runoff is filtered by a self contained bed of sand and a discharge chamber. Runoff is diverted to the bed, collected by underground pipes and then discharged into a stream or channel.

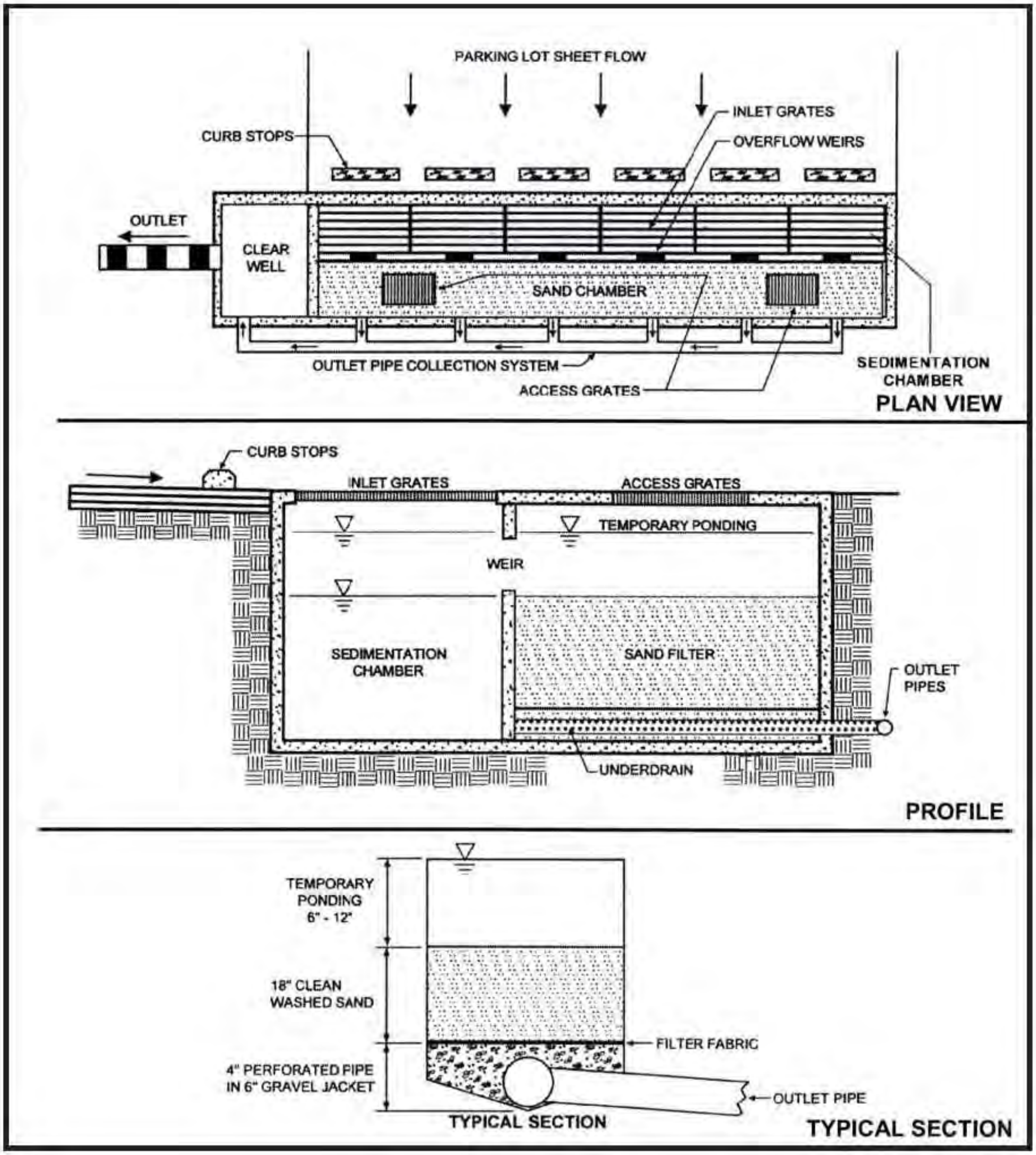


Figure 6.135: Perimeter Sand Filter. Source: Center for Watershed Protection (©2000)

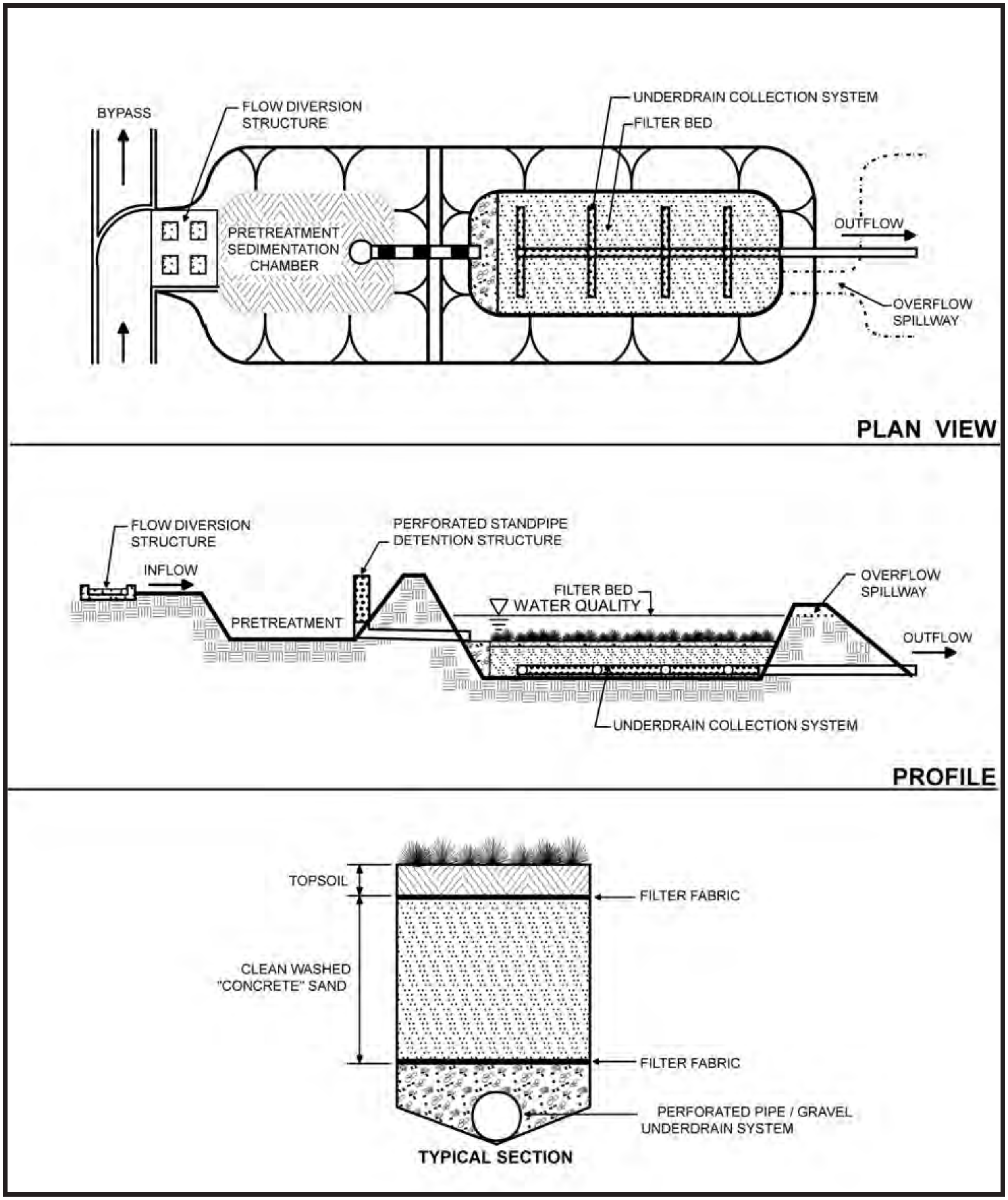


Figure 6.136: Surface Sand Filter. Source: Center for Watershed Protection (©2000)

Recommended Minimum Requirements

To avoid hydraulically overloading the device, the contributing drainage area to any sand filter should be limited to 5 acres. Sand filters should be designed as off-line practices to capture and treat only the water quality storm and to bypass the larger flows. When used in combination with sedimentation basins, sand filters should be installed as an initial pretreatment step.

Construction

Prior to start of construction, this SCM should be designed by a registered design professional as part of the overall site design for long-term water quality. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. Elevations of pipe inverts, weirs and filter beds are critical to sand filter performance and should be checked during construction.

Construction Verification

Measure the finished grades and configuration and compare against the plans and specifications. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

Maintenance and inspection of a sand filter will vary depending on the design. Periodic maintenance activities should include the following:

- Frequent inspection of overflow, removal of organic material, and removal of sediment from the sediment basin or chamber.
- Quarterly monitoring of water levels in underground filters.
- Biannual inspection for erosion of pretreatment surface and pocket sand filters.

Common Problems and Solutions

Problem	Solution
Erosion or washout.	Install a device for energy dissipation at the eroded or washed out location.
Clogging due to high sediment loading.	Stabilize adjacent contributing drainage areas or perform frequent clean-outs.
Cells collect trash and debris.	Conduct regular trash and debris removal.
Standing water.	Use corrective measures to ensure proper infiltration.

Hydrodynamic Separation

Figure 6.137: Hydrodynamic Separator. Source: MSD

Practice Description

Hydrodynamic separators, also called swirl concentrators or vortex separators, are available in a wide variety of proprietary devices. These systems target coarse solids and large oil droplets using vortex-enhanced sedimentation or cylindrical sedimentation.

These proprietary systems can provide pretreatment to other technologies in urban areas where surface SCMs are not feasible. Stormwater runoff is not detained, rather it flows through these separation systems at a designed rate controlled by the inflow pipe. They often provide pretreatment for other systems (like filters). It is noted that these devices provide no volume reduction benefits and are generally used only in a retrofit role. They are also used for stormwater hotspots where space is limited for other SCMs.

Recommended Minimum Requirements
Hydrodynamic separators may work if designed off-line with an upstream diversion structure to address larger flows. Head losses across the system should be considered. The design of the system is specific to the manufacturer. The designer should review local requirements for site grading, drainage structures, and erosion and sediment control.

Construction
The design of the system is specific to the manufacturer. Plans and specifications should be referred to by field personnel throughout the construction process. The contributing drainage area should be fully stabilized prior to the operation of the device.

Construction Verification
Check the finished elevations and configuration for all elements. Check elevations and dimensions of all pipes and structures to verify installation.

Maintenance and Inspection
Maintenance requirements and procedures are specified by the manufacturer.

- Regular maintenance is required to prevent the re-suspension of trapped pollutants. Maintenance frequency is a function of the site specific runoff characteristics.
- Maintenance is usually performed with a vacuum truck.
- Maintenance requirements and procedures are specific to each system and specified by the manufacturer.

Common Problems and Solutions
The manufacturer should be consulted if there are problems with this SCM. Maintenance requirements and procedures are specified by the manufacturer. This device is maintenance intensive due to the small capacity. If this device is not cleaned out routinely, the trapped materials may result in highly polluted discharges during the next storm event.

Catch Basin Inserts

Figure 6.138: Catch Basin Inserts. Source: Shockey Consulting Services

Practice Description

Catch basin inserts are manufactured filters designed to remove trash, debris, coarse sediments, and sometimes oils from stormwater runoff. They are located at the storm drain inlet structure, often installed beneath a catch basin inlet grate.

This device alone does not address all water quality needs. Catch basin inserts are installed to provide pretreatment of runoff from roads, parking lots, commercial and industrial sites. These inserts present an inexpensive option for pretreatment retrofit and are often used in conjunction with other downstream SCMs such as media filtration and infiltration. Manufacturer specifications should be compared to site specific targeted constituents. It is noted these devices provide no volume reduction benefits and are generally used only in a retrofit role. They are also used for stormwater hotspots where runoff pollution is unusually high and where space is limited for other SCMs. However, filters are a more effective way of treating hotspots where space permits.

Recommended Minimum Requirements

Catch basin inserts may be easily installed at most existing storm drain inlets. The design of the system is specific to the manufacturer. The design professional should ensure the capacity of the inlet remains sufficient and does not result in localized flooding. The designer should review local requirements for drainage structures and erosion and sediment control.

Construction

The design of the system is specific to the manufacturer. Plans and specifications should be referred to by field personnel throughout the construction process. The contributing drainage area should be fully stabilized prior to the operation of the device.

Construction Verification

Check the finished elevations and configuration for all elements. Check elevations and dimensions of all pipes and structures to verify installation.

Maintenance and Inspection

Frequent maintenance is critical to ensure functionality of the storm drainage system. Maintenance requirements and procedures are specified by the manufacturer.   Maintenance frequency is a function of the site specific runoff characteristics.

Common Problems and Solutions

The manufacturer should be consulted if there are problems with this SCM. Maintenance requirements and procedures are specified by the manufacturer.   This device is maintenance intensive due to the small capacity. If this device is not cleaned out routinely, the trapped materials may result in highly polluted discharges during the next storm event.

Baffle Boxes and Oil/Grit Separators

Figure 6.139: Wetland Swale. Source: Olsson Associates

Practice Description

There is a wide range of configurations and designs of proprietary baffle box or oil/grit separators. Most of these systems are installed offline, bypassing the larger flows. These systems typically have a sediment chamber sized based on Stoke's Law principles, and a chamber to trap floatables such as oils and trash.

There are proprietary and non-proprietary systems. This device is used for limited water quality enhancement in urban areas when land is not available for surface SCMs. They often provide pretreatment for other systems (like filters). Baffle boxes may be incorporated with pre-treatment filters for surface SCMs. These devices allow water to flow through and the rate is regulated by the bypass structure. It is noted these devices provide no volume reduction benefits. Baffle boxes are generally used only in a retrofit role. As a companion practice with filters, they can be used where space is limited for other SCMs or for stormwater hot spots that produce higher concentrations of pollutants than what is normally found in urban runoff.

Recommended Minimum Requirements

Baffle boxes and oil/grit separators are underground and can be adapted to almost any site as an offline treatment. There must be sufficient grade change across the bypass line to ensure that treated water returns to the main line. Specific design and performance expectations are based on the manufacturer. The designer should review local requirements for site grading, drainage structures and erosion and sediment control.

Construction

The design of the system is specific to the manufacturer. Plans and specifications should be referred to by field personnel throughout the construction process. The contributing drainage area should be fully stabilized prior to the operation of the device.

Construction Verification

Check the finished elevations and configuration for all elements. Check elevations and dimensions of all pipes and structures to verify installation.

Maintenance and Inspection

Maintenance requirements and procedures are specified by the manufacturer. Regular maintenance is required to prevent the re-suspension of trapped pollutants. Maintenance frequency is a function of the site specific runoff characteristics. Removal of trapped material is performed with a vacuum truck as needed, usually annually.

Common Problems and Solutions

The manufacturer should be consulted if there are problems with this SCM. Maintenance requirements and procedures are specified by the manufacturer. Limitations include limited pollutant removal, no volume control, frequent maintenance, proper disposal of trapped sediment, oil and grease, expensive to install and maintain when compared to other practices, and cannot be used for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols and alcohols. Also, the contributing area should be limited to one acre or less of impervious cover.

Streambank Protection: Preservation, Enhancement and Restoration

Figure 6.140: Streambank Erosion. Source: Shockey Consulting LLC, Burr Oak Woods, Jackson County, MO

Practice Description

Restoration of the streambanks becomes necessary when permanent stormwater control measures have been insufficient or nonexistent to control runoff from the disturbed areas. Streams that receive increased flow volume and velocity will likely suffer bank erosion if not protected. Streambank protection can be vegetative, structural or a combined method where live plant material is incorporated into a structure (bioengineering). Vegetative protection is frequently the least costly and the most compatible with natural stream characteristics. Because each reach of channel is unique, a professional team should be consulted to ensure the specific site characteristics and sensitivities are considered in the design and installation of protective or restorative measures. The professional team will need to focus on streambank and channel stability, upstream contributions to increased flow and volume, and specific stream characteristics that will determine stabilization design (e.g. stream grade and soil type).

Streambanks tend to erode in watersheds where surface runoff rates have increased, causing higher peak flows in the stream. As a result, the stream reforms to carry its new load. Negative impacts to the stream result from changes in the watershed, such as removal of vegetation along a streambank, removal of open space, pavement of large-scale surfaces, removal of healthy vegetation upland and installation of piped stormwater systems.

Considerations in determining which type of streambank protection to use include:

- Current and future watershed conditions.
- Discharge velocity.
- Sediment load.
- Channel slope.
- Dynamics of bottom scour.
- Soil conditions.
- Present and anticipated channel roughness.
- Compatibility with other improvements.
- Changes in channel alignment.
- Fish and wildlife habitat.

Bioengineered Streambank and Channel Protection

Bioengineering involves the use of living vegetation in combination with soil reinforcing agents such as reinforcing mats to provide bank stabilization by increasing soil shear resistance, dewatering saturated soils, and by reducing local shear stresses through increased hydraulic roughness.

Bioengineering is advantageous where there is minimal access for equipment and workers and in environmentally sensitive areas where minimal site disturbance is required. Most techniques can also be used for stream channel or bank protection. Once established, woody vegetation becomes self-repairing and needs little maintenance.

Combinations of vegetative and structural protection provide some of the advantages of both. The structures provide immediate erosion, sliding and washout protection. Vegetation provides greater infiltration than some structural methods, increases channel roughness, and filters and slows surface runoff entering the stream. Vegetation also helps maintain fish and wildlife habitat, and a natural appearance along the stream. It is important that the designer target the cause, not the symptom, of the problem in order to design an effective repair.

Combined methods can be used in areas where velocities exceed 6 feet per second, along bends, in highly erodible soils and on steep channel slopes. Common materials include cellular matrix confinement systems, grid pavers and bioengineering techniques. The upstream and downstream ends of the protection should begin and end along stable reaches of the stream. This practice should be designed for capacity at mature and self-sustaining growth and for stability at low or dormant growth.

See Appendix C and Appendix D for design manual references and other resources. More information about bioengineering practices is available from your local Natural Resources Conservation Service/Soil and Water Conservation District, the Missouri Department of Conservation, University Extension or local design professionals. See Soil Bioengineering for Slope Protection and Erosion Control Transition Mats

Vegetative Streambank Protection

Effective vegetative protection depends on locating plants where their natural characteristics provide the greatest benefit and their growth is assured. General planting information is listed below; however vegetation should be planted in accordance to the design plan with consideration to the vegetative zones. As above, vegetative protection should be designed for capacity at mature and self-sustaining growth and for stability at low or dormant growth. The location of each zone depends on the elevations of the mean high water level, the mean water level and the mean low water level as shown in Figure 6.141.

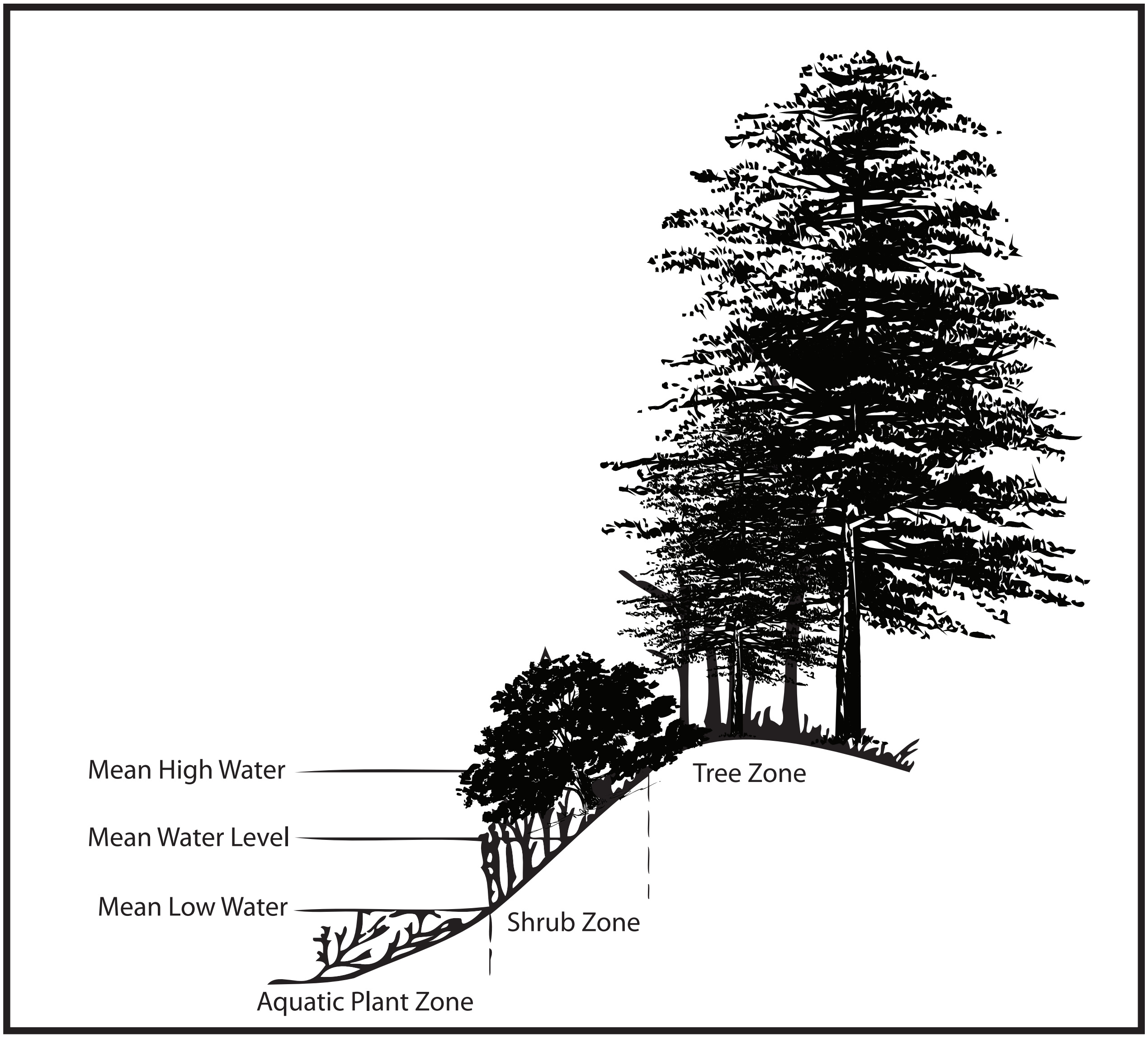


Figure 6.141: Vegetative Zones for Streambank Protection. Source: Missouri Department of Natural Resources

Aquatic Plant Zone

The aquatic plant zone includes the stream bed and is normally submerged at all times. Most often this area is not planted, yet sometimes aquatic plants are added here to achieve greater diversification in the restored stream bank community.

Shrub Zone

The shrub zone lies on the bank slopes just below the mean high water level and is normally dry, except during floods. Willows, silver maple, poplar and dog wood trees can be planted (staked) from top-of-bank to mean water line. They are preferred because they have high root densities and root depth, root shear and tensile strength is higher than that of most grasses or forbs, and they can transpire water at high rates.

- Upland trees should not be planted in the shrub zone. Refer to Appendix C and Appendix D for plant resource information, including the Grow Native! website for photos and narratives about Missouri native plants or consult the Missouri Department of Conservation, Kansas Wildlife and Parks or a professional forester for appropriate wetland shrub and tree species. Some grasses, sedges and bushes should be planted in the shrub zone if shear is not too high and plants are not submersed frequently or for long periods of time.
- Plant grasses in the spring or the fall. To seed grasses, roughen the seedbed, lime and fertilize according to soil test results. Check with the local Natural Resources Conservation Service, Missouri Department of Conservation, University Extension office or a local design professional for an appropriate seed mixture.

Tree Zone

Plant upland trees along the banks of the stream and not on the slopes. If trees provide shade to the streambank, grasses should be planted that will thrive in shady conditions.

Structural protection with engineered structures alone or bioengineered with plants should be provided in locations where velocities exceed 6-feet per second, along bends, in highly erodible soils and in steep channel slopes. Common materials include rock and revetments. Grouted riprap is not recommended, because grouted rock does not move with freeze/thaw and wetting/drying cycles. This lifting action results in voids quickly forming under grouted rock, allowing erosive forces to penetrate the structure and create potential failure of the grout and rock movement. The upstream and downstream ends of the structural protection should begin and end along stable reaches of the stream.

Streambank restoration efforts that involve structural practices or combination methods should be considered temporary if overall watershed factors are not considered in the design. Contributing erosion factors need to be corrected, because erosion will otherwise render the structural practice ineffective.

Structural Streambank Protection

Grid Pavers

Grid pavers are modular concrete units with interspaced void areas that can be used to armor a streambank while also establishing vegetation. Grid pavers are typically tied together with cables and come in a variety of shapes and sizes.

Figure 6.142: Interlocking concrete blocks along Two Mile Creek, St. Louis County. Source: K. Grimes, SWCD, St. Louis County

Cellular Confinement Matrices

Cellular confinement matrices are commercial products usually made of heavy-duty polyethylene formed into a honeycomb-type matrix. The cellular confinement matrices are flexible to conform to surface irregularities. The combs may be filled with soil, sand, gravel or cement. If soil is used to fill the combs, vegetation must also be established.

Gabions

Gabions are rock-filled wire baskets stacked to form a wall against the streambank. Gabions are not the preferred alternative for streambank protection when bioengineering practices are available to provide adequate protection. Efforts should be made to identify the sources of erosion and streambank destabilization such as upstream devegetation, increased imperviousness, extensive curb and guttering. Efforts should be made to restore upland vegetation, slow the flow of stormwater entering the stream system and reroute to alternative practices. It is better to correct the problems, otherwise gabions and similar practices such as filter fabric revetments are only temporary fixes.

Gabions are typically designed to slow the flow of stormwater. They are sometimes used on steep slopes for temporary stabilization where there is not enough room to accommodate a “softer”, vegetated solution. Gabions are very labor intensive to construct, but are semi-flexible, permeable and can be used to line channel bottoms and streambanks. They can be placed (and vegetated when possible) in a manner to provide good drainage.

Additional Considerations

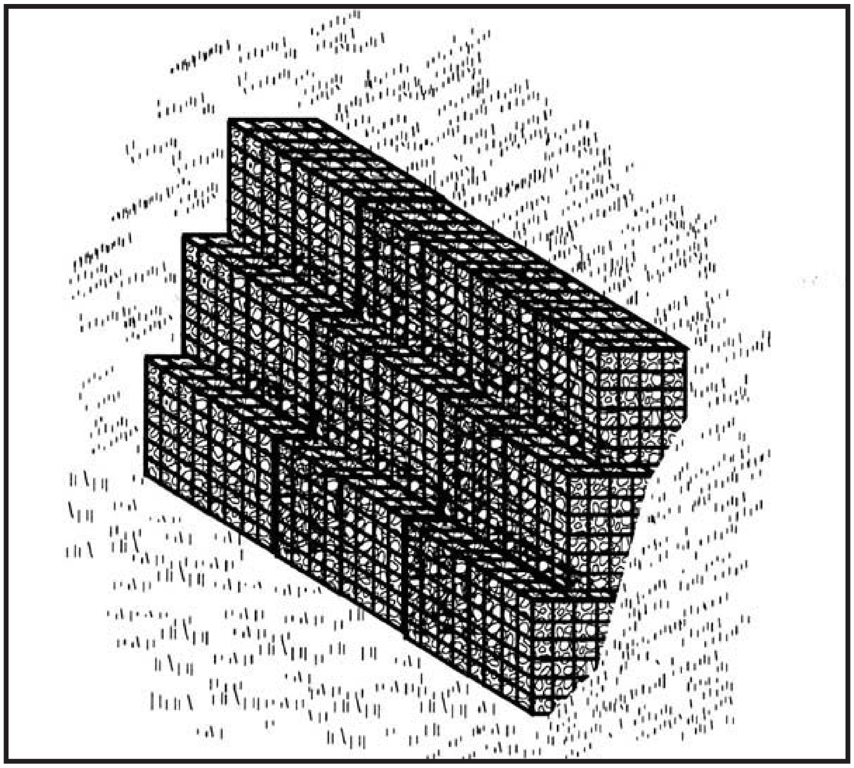


Figure 6.143 Typical gabion installation. Source: Shockey Consulting Services

Gabions are more expensive than either vegetated slopes or riprap.

The wire baskets used for gabions may be subject to heavy wear and tear due to wire abrasion by bedload movement in streams with high velocity flow. Gabions are difficult to install, requiring large equipment. Gabions are not the preferred alternative for streambank protection when bioengineering practices are available to provide adequate protection. Gabions are considered temporary. Permanent stabilization is dependant upon locating and correcting the problems contributing to erosion and destabilization. When gabions break down, the stream should already be in the process of stabilizing if erosive factors have been addressed upstream.

Recommended Minimum Requirements

Streambank protection projects should be designed by a registered Professional Engineer as part of the overall site design for long-term water quality, with significant attention given to upstream and downstream hydrologic factors and overall watershed health. Streambank and wetland work within jurisdictional waters require federal, state and possibly local permits. See Chapter 1 for regulation information.

Figure 6.144 Example of stable and unstable streambank. Source: MDC

Streambank protection should be considered in the initial design phases of any development project. An interdisciplinary team may provide the needed variety of expertise. Protection methods should focus on preserving, enhancing or restoring the stream hydraulics such that streambanks no longer erode.

Protection measures should begin and end at stable locations along the bank. Stable locations are typically where the streambed is armored with stable rocks occurring

naturally at riffles, or man-made armored sections such as culvert crossings. By working between these stable locations, the impacts of the streambank protection are limited to the channel between stable locations so the erosive forces are not transferred to another location.

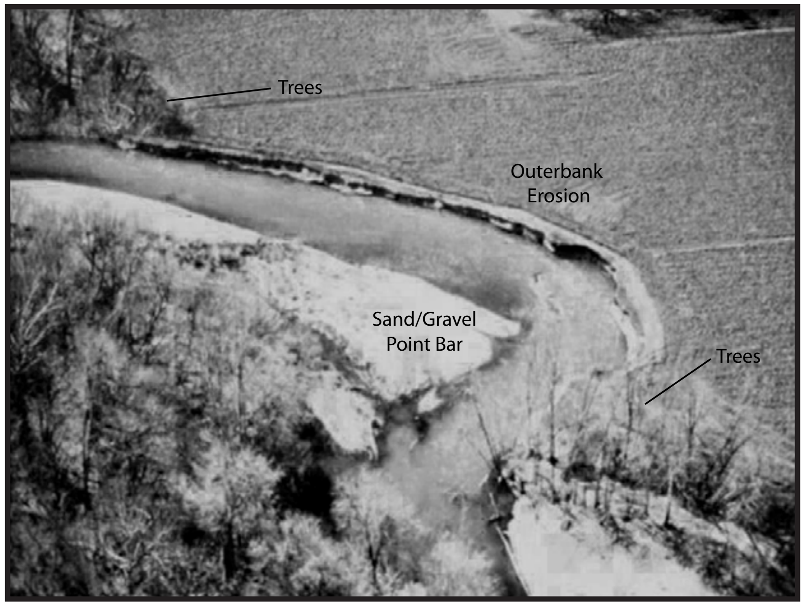


Figure 6.145 Example of stable and unstable streambank. Source: MDC

Before work is done within the channel, it should be determined if a Section 404 permit is required from the Corps of Engineers, as well as a Section 401 permit from the Department of Natural Resources. A local floodplain study may also be required. The site superintendent, job foreman and field personnel should refer to the plans and specifications throughout the construction process. The site superintendent should discuss any potential need for such permits with the site owner.

Several important considerations when designing streambank or channel protection include:

- **Velocities:** Vegetation alone may provide effective protection when stream velocities are 6-feet per second or less. Consider structural protection for velocities greater than 6-feet per second. Use the highest velocity expected, which is determined by evaluating the velocities through the full range of storms from the very frequent small events through large storm events. Allowable velocities vary depending on the soil and plant types. Refer to applicable design standards and manuals for more details.

- **Channel Bottom:** Downcutting must be stabilized before installing bank protection. An engineered grade control may be needed where downcutting is severe.

- **Streambank Plantings:** Consider the natural growth needs, patterns and preferences of selected planting stock when reestablishing the streambank community.

- **Plant Selection:** Use native or adaptive plant materials for establishment and long term success, because adapted plants are easier to establish and require less maintenance. See Appendix C and Appendix D for references about guiding plant selections.

- **Structural Methods:** Constructed “hard surfaced” features may be needed in especially challenging spots such as bends in the channel or changes in channel slope or where changes in hydrology, sediment load and channel alignment are occurring.

- **Combined Methods:** Many bioengineering practices (i.e. use of “living” structures) are useful to protect streambanks and channels. See Bioengineered Streambank and Channel Protection above.

- **Permits Requirements:** See Chapter 1 for regulation and permit requirements.

Construction

Initial Site Considerations

- Before starting construction, ensure all plans follow local, state and federal government regulations for any stream modification within jurisdictional waters. See Chapter 1 for regulation and permit requirements.

- Prior to excavation activities of any type, call 800-DIG-RITE (344-7483) to obtain utility locations.

- Examine the channel bottom before streambank protection measures are installed. Determine the need for grade control.

- Locate stable points along the channel to serve as anchor points for stream protection structures.

Follow design specifications for clearing, grubbing and grading. Grid pavers, cellular confinement matrices, gabions or other proprietary products should be designed and constructed into the project in accordance with manufacturer's guidelines and as specified in the design plan.

When filling products with rock, only durable crushed limestone, dolomite or granitic rock should be used. Shale, siltstone and weathered limestone should not be used because of their solubility or tendency to crumble. Depending on soil type, a filter fabric or a granular filter may need to be placed between streambank material and gabions. Use attractive facing stone toward the front of the wall.

Establish desirable vegetation where possible in between rocks and materials within the pavers, matrices or gabions. Otherwise, invasive and poorly rooting plants will take over the practice, reducing its effectiveness. Desirable vegetation will also increase habitat value.

Erosion Control

Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete. Use temporary diversions to prevent surface water from running onto the streambank protection area. Route overland flow so it maintains the least possible velocity and exits the project site at a protected location. This information should be outlined in the community's stormwater pollution prevention plan associated with state, local or federal permits. See Chapter 1 for regulation and permit information.

Plant vegetation immediately after construction to promptly stabilize all disturbed areas.

Safety

Store all construction materials well away from the stream to avoid transport of polluted runoff or materials to the stream.

Clear, grub and grade the streambank surface to prepare for installing the matrices. Install systems according to engineered design plans and manufacturer's recommendations.

At the completion of each workday, move all construction equipment to a safe storage area out of and away from the stream to prevent damage from flooding. While working in streams, whether flowing or not, the following precautions should be taken:

- Avoid working above steep slopes on the streambank where cave-ins are possible.

- Fence area and post warning signs if trespassing is likely.

- Provide a means for draining the construction site if it becomes flooded.

Construction Verification

For vegetative protection, check to see planting and seeding was done in compliance with the design specifications. For structural protection, check cross section of the channel, thickness of protection and confirm the presence of filter cloth between the protection and the streambank.

Maintenance and Inspection

Bank stability and vegetation should be assessed during routine inspections and after each storm event during the initial 2 years following construction. If any minor bank instabilities are documented, the repair should include back-filling with soil, installing erosion control blanket or bonded fiber matrix, planting seed blends and vegetative cover recommended in the plans.

Significant bank instabilities should be addressed by a professional design engineer. The extent of the project areas should be monitored with great frequency at project completion and less often as the project establishes, as presented below.

Table 6.18: Monitoring Frequency Following Plant Establishment

Growing Seasons	Frequency of Monitoring
1 - 2 years	Bi - Weekly
3 - 5 years	Bi-Monthly
Project Life	Two Inspections Annually

Maintenance activities should be in response to any new bank instabilities or vegetation issues detected. Maintenance activities may consist of weed control, bank stabilization and replanting vegetation that has died or eroded. It is important to identify what caused any issues so their reoccurrence can be prevented.

Bare areas of soil greater than 1 ft^2 shall be reseeded immediately upon discovery and protected from soil erosion. For any new plantings, adequate soil moisture is critical to plant establishment, and adequate soil moisture must be maintained immediately after each plant is sowed or set.

The project should require the contractor or property owner to maintain the plants throughout the first full growing season until they become established. Plants are more susceptible to mortality during the first two weeks of their growth and often require supplemental watering.

It is also important that other environmental and man-made stresses be monitored and timely adjustments be made to take these stresses into account. Some anticipated stresses include:

- Herbivory or Grazing (insects, deer, livestock).
- Vandalism.
- Wildlife Damage (rabbits, deer, beaver, muskrat).
- Insect infestations (grasshoppers, army cutworm, spider mites).
- Disease (not a frequent problem with non-horticultural varieties).
- Water stress (drought early on, typically the design is flood tolerant).
- Weather Damage (wind, hail).
- Weed Infestation.

Streambank maintenance after construction is the responsibility of the land owner, municipality or sewer district. The landowner needs to understand their responsibility and the state and local requirements in their area. Larger issues can be addressed through cooperative watershed planning and partnerships with regional planning groups.

Common Problems and Solutions

Problem	Solution
Variations in topography on-site indicate protection will not function as intended.	Consult with a registered Professional Engineer, changes in plan may be needed.
Design specifications for vegetative or structural protection cannot be met.	Consult with registered Professional Engineer, substitution may be required. Unapproved substitutions could result in erosion damage to the streambank and cause project failure.
Erosion of streambank; caused by inadequate vegetation, improper structural protection or an increase in stream velocity due to upstream development.	Repair erosion, establish adequate vegetation or structural protection and reduce stream velocities.
Slumping failure or slides in streambank; caused by steep slopes.	Repair a slide by excavating failed material and replacing with properly compacted fill. Consider flattening the slope and consult the Professional Engineer.

Rock Lined Channels

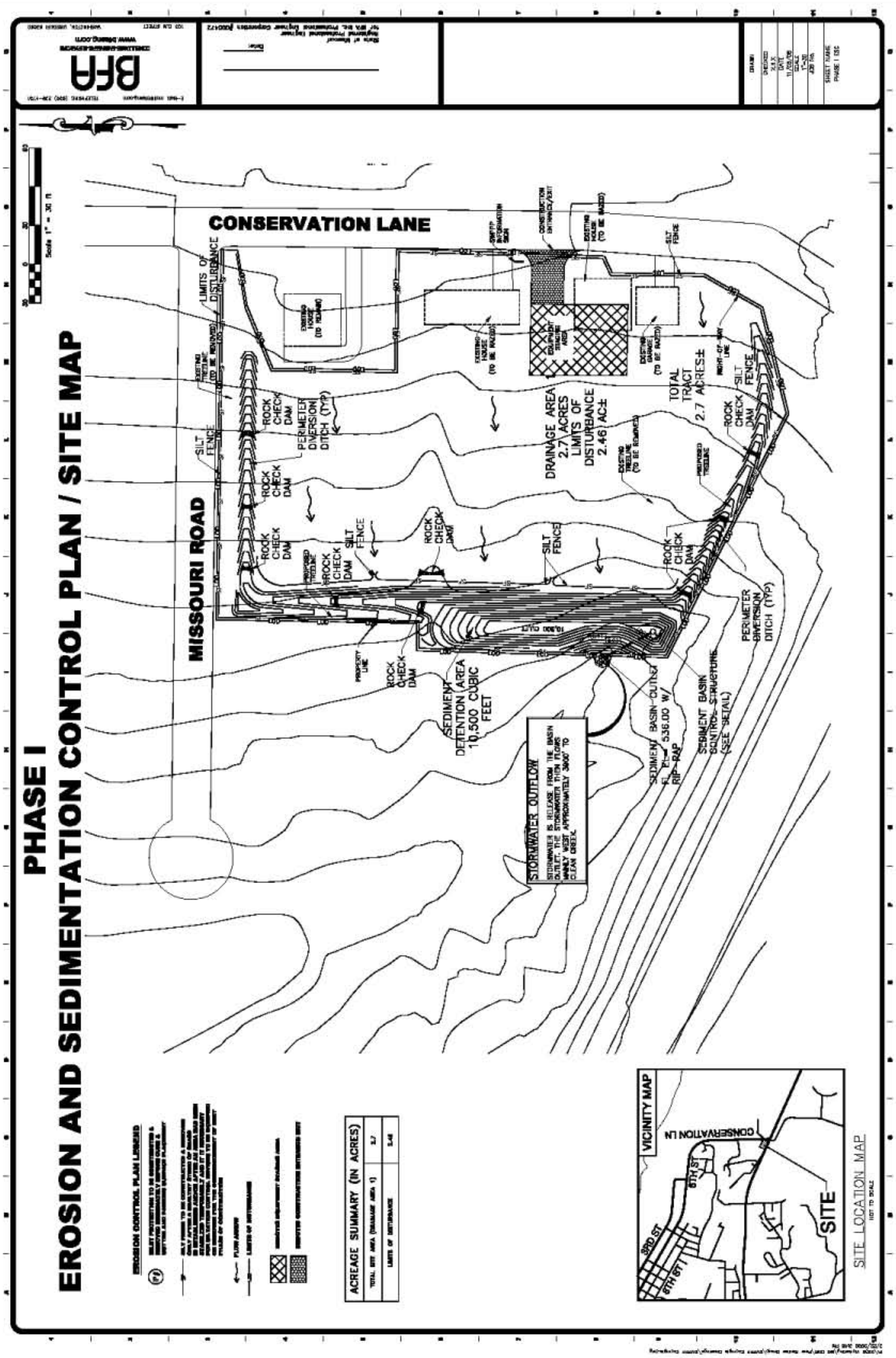
Highway drainage designers are ultimately left with the task of capturing runoff that does not infiltrate and then routing it via storm sewer to an outlet at some location. In the distant past, it was common to let this runoff discharge directly to a receiving water body, often resulting in an actively erosive area. Later, it became common to line the channel area with various sized rocks (riprap) in order to solve the problem.

Riprap is still used, however it is not always the most structurally sound nor is it the most aesthetic approach. Natural and synthetic geotextile reinforcements may be a suitable alternative and are available to fit a variety of needs. Choosing between these options depends a great extent on the nature of the problem. Product specifications for strength and applications should be examined to choose the proper material. Another option is compost-grouted riprap, in which compost is sprayed into voids and serves as a root medium for native plants.

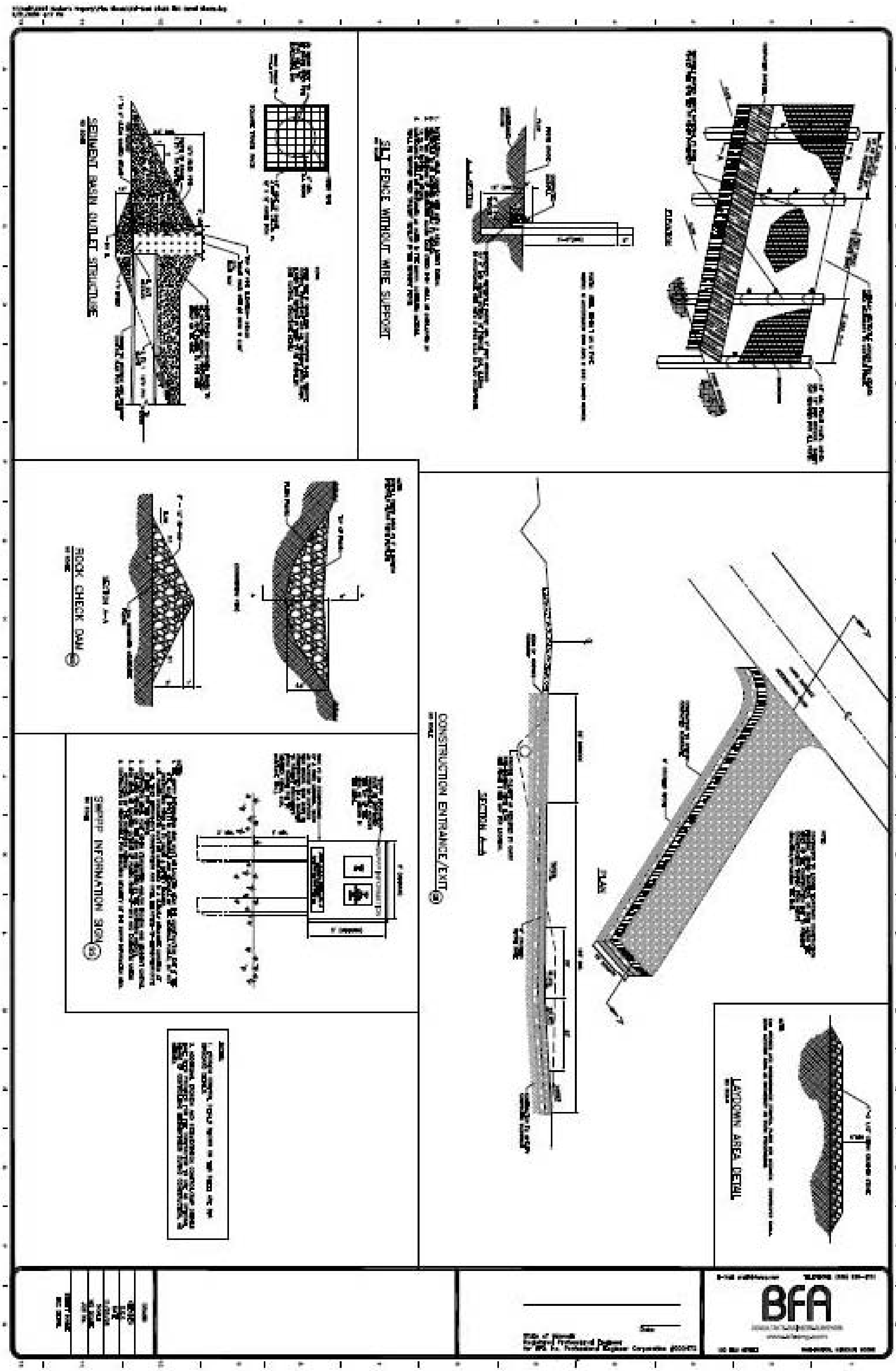
As with grade controls, these reinforcement methods can be part of an initial installation or easily retrofit if a problem is identified and in need of a solution. However, erosive factors need to be addressed elsewhere in the watershed to avoid further failure.

- Rock lined channels require properly sized, graded, bedded and placed rock that rises and settles with soil movement.
- Stream banks should be sloped at 2:1 or flatter.
- In some cases, it might by beneficial to place filter fabric or a granular filter between the rock and the natural soil.
- Construct the riprap layer with sound, durable rock. Refer to plan for gradation and layering.
- Large and small rocks are required to lock in pieces and should not be flat or elongated.
- Place the toe of the rock at least 2-foot below the stream channel bottom or below the anticipated scour depth. Install toe walls as specified in plan.
- Extend the top of the riprap layer at least up to the two year water surface elevation. Vegetate the interface and remainder of bank.

APPENDIX A
SITE MAP, DETAIL SHEET AND GRADING PLAN



Site Plan. Source: BFA



Detail Sheet. Source: BFA

APPENDIX B
GLOSSARY

A

Accelerated Erosion See Erosion.

Acidic A material with a pH of less than 7.0. Soil nutrients are generally less soluble and less available to plants in moderately or strongly acid soils. Agricultural lime is commonly applied to acidic soils to increase the pH.

Acre An area of measurement equal to 43,560 square feet.

Aeolian Wind deposited material such as loess or dune sands.

Aggregate Sand, gravel, crushed stone or slag, usually having a known range of particle sizes. Used with a cementing medium to form concrete or alone as in a roadway bed or railroad ballast.

Agronomy The theory, study and practice of field crop production and soil management.

Alkaline A material with a pH greater than 7.0.

Alluvial Soil Soil formed from materials transported in suspension by flowing water and deposited by sedimentation.

Anchor Trench A long, narrow ditch in which the edges of a material (e.g. silt fence, erosion control blanket or geotextile) are buried to hold it in place.

Angle of Repose The maximum angle of slope (measured from a horizontal plane) at which loose, non-cohesive material will come to rest. The angle of repose for unconsolidated soil varies with the soil grain size, grain shape and moisture content. To maintain stability, cut or fill slopes should not exceed the angle of repose or slippage may occur.

Anti-Seep Collar A plate of metal, high-density plastic or butyl rubber attached perpendicularly to the outside of a pipe placed through an embankment. Used to prevent water from flowing unabated along the outside of the pipe causing soil piping and structure failure.

Application Rate The quantity (mass, volume or thickness) of material applied per unit area.

Apron Protective material laid on a streambed or ground surface to prevent scour at a culvert outlet, abutment, toe of a structure or slope or similar location.

Aquifer An underground, porous, water-bearing geological formation composed of a layer of permeable rock, sand or gravel that provides a groundwater reservoir.

Armor A protective coat or artificial surface on streambeds, banks, shores or embankments used to resist erosion or scour. Examples of hard armor include concrete and riprap. Soft armor includes flexible geosynthetic support systems used with vegetation.

Articulated Block Systems Concrete blocks linked by cables or interlocking pieces that are flexible, porous and can accommodate growth of herbaceous and woody vegetation while offering the strength and durability of a hard armor.

B

Best Management Practice, or BMP The preferred methods and products that will correct or control erosion, sedimentation or water quality degradation on a specific site for particular site conditions.

Backfill Earth or other material used to replace material removed during construction, such as in culvert, sewer and pipeline installations.

Base Course (Base) A layer of material of specified thickness placed on the subgrade to distribute load, provide drainage and minimize frost action.

Bedding The soil or other material on which a pipe or conduit is supported.

Bench A step in a slope. Formed by a horizontal surface and a surface inclined at a steeper angle than the entire slope.

Bentonite (Sodium Bentonite) A highly plastic clay that swells extensively when wet. Used to seal soil to reduce seepage losses from ponds and lagoons.

Berm (1) A ridge of earth constructed to direct the flow of surface water. (2) A shelf that breaks the continuity of a slope. (3) The embankment of a pit or pond that may be wide and solid enough for vehicular traffic.

Binder (Emulsion, Tackifier) Natural or synthetic additive that causes an otherwise non-cohesive material to become bound into a cohesive matrix.

Biodegradable Ability of a material to breakdown or decompose under natural conditions and processes, within an acceptable time frame, without polluting the environment.

Bioengineering A method of construction using living plants or plant materials in combination with inorganic materials. The practice brings together biological, ecological and engineering concepts to produce living, functioning systems used to prevent erosion and control sedimentation. Also, it often provides wildlife habitat.

Biological Stability Ability to resist degradation from exposure to microorganisms.

Blanket Rolled materials consisting of coir (coconut fiber), jute, straw, wood fiber or various synthetic materials used to prevent erosion, trap sediment, protect seed and promote the growth of vegetation. They can be either degradable or permanent.

Blinding (Clogging) The condition whereby soil particles block the voids at the surface of a geotextile, thereby reducing the rate of water flow through the geotextile.

Bridging (Soil) The formation of large voids due to inadequate compaction of earth material or the inclusion of improper fill materials.

Broadcast The application of material scattered or sprayed on the soil surface. Broadcast seeding is a uniform distribution of seeds over the entire planted area.

C

CCIS™ A Certified Compliance Inspector of Storm water as designated by Stormwater USA.

CESSWI™ A Certified Erosion, Sediment and Storm water Inspector as designated by EnviroCert International.

CISEC™ A Certified Inspector of Sediment and Erosion Control as designated by CISEC Inc.

CPESC ™ A Certified Professional in Erosion and Sediment Control as designated by EnviroCert International.

CPSWPPP™ A Certified Preparer of Storm water Pollution Prevention Plans as designated by Stormwater USA.

CPSWQ® A Certified Professional in Storm water Quality as designated by EnviroCert International.

Canopy (Plant) The foliage of a tree, shrub or herbaceous plant. The area covered by the plant canopy is protected from splash erosion.

Canopy (Inlet) A principal spillway pipe with the inlet cut at an angle of 33, 45 or 56 degrees designed as an anti-vortex device that maximizes water flow through the pipe.

Carbon Black Material consisting primarily of elemental carbon used as an additive for plastic geosynthetic production. It imparts a black color to the compound, which retards aging by ultraviolet light from the sun.

Catch Basin A receptacle for diverting surface water to a sewer or subdrain, having at its base a sediment bowl to prevent the admission of coarse material into a sewer or stream.

Cation Exchange Capacity, or CEC The capacity of a soil for ion exchange for cations between the soil and soil solution. CEC is used as a measure of fertility and nutrient retention capacity.

Cellular Confinement System A synthetic grid with open spaces filled with soil, sand, gravel or concrete. The matrix mechanically stabilizes these materials and is used for erosion control and load support applications.

Certified Seed Seed that has been analyzed by a state association test laboratory for percent germination, weed seed content and purity.

Channel A natural stream or excavated ditch that conveys water.

Channel Erosion See Erosion.

Channel Stabilization Protection of the sides and bed of a channel from erosion by controlling flow velocities and directions or by lining the channel with vegetation, riprap, concrete or other material.

Check Dam (Rock Check Structures) Temporary barriers of 3 to 6 inch rock constructed across a swale or drainage ditch. Used to reduce the velocity of concentrated storm water flows, reduce degradation and to trap sediment.

Chemical Stability The ability to resist chemicals (e.g., acids, bases, solvents, oils and oxidation agents) and chemical reactions, including those catalyzed by light.

Chute A steeply inclined channel, usually lined with rock or concrete, for conveying water from a higher to a lower level.

Clay (1) Mineral particles less than .002 millimeters in equivalent diameter. (2) A soil containing more than 40 percent clay. Clay soils exhibit plasticity when moist, but are hard when dry.

Clogging See Blinding.

Coefficient of Permeability (k) The rate of discharge of a fluid per unit cross sectional area of a geotextile under a hydraulic gradient.

Cohesive Soil An unconfined soil that has considerable strength when air dried and significant resistance to disintegration when submerged in water.

Coir Organic fiber from the outer shell of the coconut, used as a mulch and in the manufacture of erosion control blankets, geotextiles and coir tubes for scour protection and planting in bioengineering applications.

Compaction The application of mechanical forces to the soil to make it denser and less porous.

Concrete A hard, strong building material composed of water, a cementing material such as portland cement and a mineral aggregate such as sand or gravel.

Concrete Armor Blocks Interlocking blocks of precast concrete used for channel linings and streambank stabilization.

Conduit Any channel or pipe for transporting water.

Conservation District A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water and related resource conservation, use and development within its boundaries. Often called a soil conservation district or soil and water conservation district, it is usually a subdivision of state government with a local governing body, but with limited authorities.

Consistency The relative ease with which a soil can be deformed. Soil moisture content directly influences how a soil behaves when subjected to compression.

Contaminant A secondary material added by human or natural activities which may, in sufficient concentrations, render the primary material or atmosphere unacceptable.

Contour An imaginary line on the surface of the earth connecting points of the same elevation.

Coverage The surface area to be covered by a specified material. For roll goods, allowance is made for a defined overlap of the edges of the material.

Creep (1) Slow mass movement of rock or soil material down slopes primarily driven by gravity which is not usually perceptible except to observations of long duration. (2) The slow change in length or thickness of a material under prolonged stress.

Crest Elevation (1) The maximum elevation of surface water under consideration. (2) The highest elevation of a structure or component.

Critical Areas Regions highly susceptible to erosion such as an area subjected to concentrated water flow.

Critical Depth Water depth in a conduit at which certain conditions of maximum flow will occur.

Critical Slope (1) The slope at which a maximum flow will occur at minimum velocity. (2) The maximum angle with the horizontal axis at which a sloped bank of soil or rock of a given height will stand unsupported. See Angle of Repose.

Critical Velocity The average velocity of flow when flow is at critical depth.

Culvert A conduit for conveying surface water through an embankment.

Cut and Fill A process of moving earth by excavating part of an area and using the excavated material for adjacent embankments or deposit areas.

D

d50 The sieve opening size that allows 50 percent of a given sample to pass through.

Dam An embankment constructed of compacted soil materials usually across a stream or area of concentrated water flow.

Darcy's Law A law describing the rate of flow of water through saturated porous media.

Deformation A change in the shape of a specimen, (e.g., an increase in length produced as a result of the application of a tensile force).

Degradable The ability of a material to break down or decompose into lesser components.

Degradation (1) The loss of desirable properties by a material as a result of some process or physical/chemical phenomenon. (2) The progressive general lowering of a stream channel by erosion.

Density The mass of a substance per unit volume.

Department of Natural Resources, or DNR The state agency in Missouri responsible for preserving and protecting the state's natural and cultural resources. Along with EPA, the Department of Natural Resources is authorized to regulate the NPDES program, which includes storm water runoff permitting. The department also provides grants and low-interest loans to public entities for sediment control, water pollution control and related information and

education projects.

Design Flow A quantity of flow expected at a certain point as a result of a design storm or flood frequency.

Design Frequency The recurrence interval for hydrologic events used for design purposes. As an example, a design frequency of 50 years means a storm of a magnitude that would be expected to occur on the average of once in every 50 years.

Design Life The length of time for which it is economically sound to require a structure to serve without major repairs or replacement.

Design Standards The defined conditions where a specific conservation practice or set of practices are to be used.

Design Storm A selected rainfall pattern of specified amount, duration, intensity and frequency that is used to calculate the volume of water runoff and peak discharge rate.

Dewatering The removal of surface or subsurface water such as removing water temporarily impounded in a holding basin or pond.

Dew Point The temperature at which water vapor starts to condense in cooling air at the existing atmospheric pressure and vapor content.

Dike An embankment or wall constructed to prevent flooding.

Discharge A volume of fluid passing a given point per unit time. The flow rate of storm water is commonly expressed as cubic feet per second.

Diversion A channel and ridge of earth constructed to divert surface runoff water from one area to another for disposal at a non-erosive velocity.

Drainage Interception and removal of groundwater or surface water, by artificial or natural means.

Drainage Area A geographical area that contributes runoff water to a common point.

Drainage (Soil) The frequency of saturation and duration of time needed for water to flow through soil.

Dredging The process of removing sediment from a watercourse such as a river or reservoir.

Drop Inlet A structure in which the water drops through a vertical riser connected to a discharge conduit or over the crest of a vertical wall to a lower elevation.

Drop Structure A structure in a channel or conduit that permits water to drop to a lower level.

Dry Well A steel catch basin with open bottom and perforated walls. Used to store surface runoff for infiltration, or recharge, into the ground.

E

Effective Calcium Carbonate, or ECC A measure of the ability of a liming material to

neutralize soil acidity, expressed as a percentage. Agricultural lime is approximately 50 percent ECC.

Ecosystem A system formed by living organisms interacting with their nonliving environment.

Effluent A material that flows out from the point of concern. (e.g., sewage water or other waste liquids flowing out of a reservoir basin or treatment plant).

Embankment A mound of earth or stone built to hold back water or to support a roadway.

Emergence The process of a plant seedling rising above the soil surface.

Emulsion See Binder.

Environmental Protection Agency, or EPA The federal agency responsible for the enforcement of the Clean Water Act. See Resource Inventory List for more information.

Energy Dissipater A structure installed at the outlet of a channel, drop structure or conduit to absorb the force of high-velocity flow. It may consist of riprap, linings, baffles, staggered blocks, etc.

Equivalent Opening Size, or EOS Number of the U.S. Bureau of Standards sieve (in milimeters or inches) having openings closest in size to the diameter of uniform particles that will allow 5 percent by weight to pass through the material. Used to select filter fabric for filtration and separation usage.

Equivalent Neutralizing Material, or ENM See ECC.

Erosion The process by which soil particles are detached, transported and deposited by wind, water, ice or gravity. The following terms are used to describe different types of erosion:

> **Accelerated erosion** Erosion much more rapid than natural or geologic erosion, primarily as a result of human activities.
>
> **Channel erosion** The widening, deepening and headward cutting of small channels and waterways due to erosion caused by increased frequency of bank full (channel forming) flow.
>
> **Gully erosion** The erosion process whereby runoff water accumulates in narrow channels removing the soil to considerable depths over relatively short time periods. When surface channels cannot be smoothed out by normal agricultural tillage operations, they are called gullies.
>
> **Sheet erosion** The gradual removal of a fairly uniform layer of soil from the land surface by a thin evenly distributed sheet of runoff water.
>
> **Shoreline erosion** The loss of soil materials due to the wave action of a permanent waterbody such as a pond, lake or ocean.
>
> **Splash erosion** The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.
>
> **Rill erosion** The erosion process whereby numerous small channels only several inches deep are formed. Commonly occurs on recently disturbed and exposed soils. Rills are shallow enough to be removed by normal agricultural operations.
>
> **Saltation** The movement of soil particles by rolling or a series of short bounces along the ground surface due to the wind.

Suspension The transport of soil particles by the wind for relatively long distances.

Surface Creep The transport of soil particles by the wind along the surface of the earth.

Erosion Control The prevention or reduction of soil particle movement. Erosion control reduces soil detachment, transport and deposition.

Erosion Control Blanket Temporary or permanent fabricated materials that protect the soil and enhance the establishment of vegetation.

Erosion Control Technology Council, or ECTC A division of the International Erosion Control Association, or IECA, which develops standards and guidelines for products and testing of materials.

Evaporation The conversion of water from liquid to vapor form.

F

Fabric See Geotextile.

Fabric Formed Concrete Systems Geotextile tubes and mattresses filled with concrete to provide a hard armor protection system.

Fabric Wrapped Drain An inner core of a porous medium such as sand, gravel or a corrugated pipe with an outer geotextile wrap or sheath used to collect and remove excess water.

Fascine (Wattle) Bundles of tree or shrub branch cuttings tied together and anchored in trenches with wooden stakes. Used for a variety of slope stabilization projects.

Fertilization The process of adding soil nutrients to the soil to stimulate plant growth. The percentage of available nutrients in bulk fertilizer is labeled as percent nitrogen, percent phosphorus and percent potassium. A 100-pound bag of 12-12-12 is 12 percent nitrogen, 12 percent phosphorus and 12 percent phosphate. The bag contains 12 pounds of each nutrient along with 64 pounds of inert ingredients.

Fill (Embankment) A bank of soil, rock or other material constructed above the natural ground surface.

Filter Cloth See Geotextile.

Filter Strip A wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants, and reduce storm water flow and velocity. Designed to accept an even distribution of surface runoff; their effectiveness is reduced if a channel forms, or if high velocity flows occur.

Filtration The process of retaining soils or other materials while allowing the passage of water or fluids.

Finished Grade The final elevation of the ground surface conforming to the approved construction plan.

Flood An overwhelming quantity of water. Measured in terms of either water level or discharge rate.

Floodplain A relatively level surface of stratified alluvium that adjoins a water course and is

subject to periodic flooding, unless protected artificially by a dike or similar structure.

Footing The supporting base or ground work of a structure.

Freeboard The vertical distance between the elevation of the design high-water level and the top of a dam, diversion ridge or other water control device.

Freeze-Thaw Resistance the property of solids to resist cyclical freezing and thawing.

Friction Angle An angle, the tangent that is equal to the ratio of the friction force per unit area to the normal stress between two materials.

Frost Heave The raising of a surface or object due to the accumulation of ice in the underlying soil.

G

Gabion A galvanized or polyvinylchloride-coated steel wire mesh basket filled with stones, broken concrete or other dense, erosion-resistant material. Individual baskets are usually linked together to form part of a larger unit. Used to protect channel banks, shorelines or steep slopes from erosion.

Gauge Standard measurement of the thickness of metal sheets or wire (and bearing a relation to the weight of the metal).

Geocomposite A manufactured material using geotextiles, geogrids or geomembranes in laminated or composite form.

Geogrid A net-like polymeric material used to reinforce, stabilize or contain soil, rock, earth or other material in a wide variety of applications including internally reinforced soil walls, segmental retaining walls, steep slopes, etc.

Geomembrane A synthetic impermeable membrane used to contain liquids or sediment.

Geosynthetics Any synthetic material, including geotextiles and geomembranes, or any combination thereof, used with foundation, soil, rock, earth or any other geotechnical engineering related material, as an integral part of a structure or system.

Geotechnical Engineering The application of the laws and principles of science and mathematics to solve problems related to the materials of the earth's crust. It includes the fields of soil mechanics, rock mechanics, and many of the engineering aspects of geology, geophysics, hydrology and related sciences.

Geotextile (Fabric, Filter Cloth) A woven, nonwoven or microfilament water permeable material, either natural or synthetic, used to filter liquids and to prevent the movement of sediment, to separate different materials or to reinforce and strengthen them.

Germination The beginning of plant growth. The sprouting of roots, stem and leaves from seed.

Glacial Till Material deposited by glaciation, usually composed of a wide range of particle sizes, that has not been subjected to the sorting action of water.

Gradation The distribution of particle sizes in a material.

Grade (1) To level off to a smooth horizontal or sloping surface. (2) A reference elevation. (3) Particle size distribution of an aggregate. (4) The slope of a plane.

Grade Stabilization Structure A structure, usually a combination of an earth embankment and mechanical spillway, installed to discharge water from a higher to a lower elevation in order to control erosion, head-cutting or to reduce channel grade.

Gradient See Slope.

Great Rivers Alliance of Natural Resources Districts, or GRAND Regional association of conservation districts serving the urban conservation needs of eight Missouri and Illinois counties in the St. Louis metropolitan area.

Granular A description of the uniformity of grain size of gravel, sand or crushed stone.

Gravel (1) Soil particles with diameters between 2 millimeters and 3 inches. (2) Loose, rounded fragments of rock commonly used to surface roads.

Ground Cover Any vegetation producing a protective mat on or just above the soil surface. Usually refers to low-growing herbaceous plants.

Groundwater Level See Water Table.

Grout A fluid mixture of cement, water and sand or other fillers that can be poured or pumped easily. Used to fill the voids between riprap, culverts or other structures in channels or slopes to prevent or reduce erosion or inadvertent water flow.

Gully Erosion See Erosion.

H

Head Pressure measured as an equivalent height of water. Measured in feet or pounds per square inch.

Headcut The uphill end of a gully where water overfalls to a lower level and active erosion occurs.

Herbaceous A non-woody plant.

High-Density Polyethylene, or HDPE A synthetic polymer used for geomembranes and pond liners.

Horizon A layer of soil distinguishable from adjacent layers by characteristic physical and chemical composition. Soil horizons are commonly referred to as topsoil, subsoil and parent material. “A” horizon: the uppermost layer usually contains organic matter. “B” horizon: the layer which accumulates material leached from the “A” horizon. “C” horizon: undisturbed parent material from that the overlaying layers have developed.

Humus See Organic Matter.

Hydraulic Gradient A line that represents the relative force available due to the potential energy available. This is a combination of energy due to the height of the water and internal pressure. In an open channel the line corresponds to the water surface. In a closed conduit,

if several openings are placed along the top of the pipe and open end tubes inserted, a line connecting the water levels in the tubes represents the hydraulic energy.

Hydraulic Mulch Processed materials such as wood and paper products, cotton or straw fibers that are applied by special equipment using a water-based slurry that is sprayed on the soil surface.

Hydraulic Radius The cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit. The ratio of area to wetted perimeter.

Hydraulics The science and technology of the mechanics of fluids.

Hydric Soil Soils that are wet long enough to periodically produce anaerobic conditions, thereby influencing the growth of plants.

Hydrograph A chart showing for a given point on a stream the runoff rate, depth, velocity or other property with respect to time.

Hydrologic Soil Groups Categories of soil based upon their runoff producing characteristics. Group A soils have low runoff potential. Group D soils, the other extreme, have high runoff potential. Hydrologic soil groups are listed in NRCS soil surveys, a publication available at NRCS/Conservation District offices.

Hydrology Science dealing with the distribution and movement of water.

Hydrophilic Molecules and surfaces that have a strong affinity for water molecules.

Hydrophobic Molecules and surfaces that have little or no affinity for water molecules.

Hydrophytic A plant adapted to growth in water or saturated soil.

Hydroseeding Spreading of seed hydraulically in a water medium. Mulch, lime and fertilizer can also be incorporated into the sprayed mixture.

Hydrostatic Pressure A state of stress in which all the principal stresses are equal (and there is no shear stress), as in a liquid at rest; the pressure in a liquid under static conditions; the product of the unit weight of the liquid and the difference in elevation between the given point and the free water elevation. Measured in pounds per square inch.

Hygroscopic A material that attracts, absorbs and retains atmospheric moisture.

I

International Erosion Control Association, or IECA P.O. BOX 774904, Steamboat Springs, Colorado 80477-4904 or phone 800-455-4322. Serves as a global resource for people who share a common responsibility for the prevention and control of erosion. The Great Rivers Chapter serves Iowa, Kansas, Missouri and Nebraska. Contact Great Rivers Chapter of IECA at 600 Broadway, Suite 200, Kansas City, MO 64105 or call 816-474-4240.

Impermeable Does not permit passage of a fluid or a gas.

Impervious Impenetrable. Soil that is resistant to the entrance of water, air or plant roots.

Incorporate To mix materials such as fertilizer or lime into the soil with tillage operations.

Infiltration The downward entry of water into the surface of soil.

Inflow The water discharged into a point of concern.

Inoculation (of seeds) The addition of nitrogen-fixing bacteria (inoculant) to legume seeds or to the soil in which the seeds are to be planted. The bacteria convert atmospheric nitrogen into a form available for plant growth.

Inorganic Composed of matter not of plant or animal origin.

Inorganic Soil See Mineral Soil.

Intermittent Stream A stream, or reach of a stream, that only flows during wet seasons; usually less than 50 percent of the year.

K

Kansas Department of Health and Environment, or KDHE The state agency in Kansas that regulates the NPDES Program including storm water runoff permitting. See Resource Inventory List for more information.

L

Landscaping The placement of sod, seed, trees and other vegetation after final grading is completed.

Lapped Joint A joint made by placing one surface partly over another surface and bonding or fastening them together.

Leachate Liquid that has percolated through a material and contains soluble components removed from that material.

Leaching The removal into solution of soluble materials by percolating water. Generally refers to the movement of soil nutrients to a deeper soil horizon, making them unavailable for plant growth. It can also refer to the movement of contaminants through the soil and into the groundwater.

Legume Any member of the pea or bean family which includes peas, beans, clovers, alfalfas, lespedezas and vetches. Most are nitrogen-fixing plants.

Lift An applied or compacted layer of soil, asphalt or waste. Also referred to as a course.

Lime, Agricultural A soil amendment containing calcium carbonate and other materials used to neutralize soil acidity and furnish calcium for plant growth.

Liner A layer of emplaced materials that serves to restrict the escape of liquids or solids placed within an impoundment. This includes reworked or compacted soil and clay, asphaltic and concrete materials, spray-on membranes, polymeric membranes or any substance that serves the above stated purpose. The portion of a reservoir responsible for the first line of defense against seepage; that is, the part immediately adjacent to the liquid being held.

Liquefaction Loss of strength of a saturated soil resulting from the combined effects of

vibrations and hydraulic forces, thereby causing the material to flow.

Loam A soil textural classification in which the proportions of sand, silt and clay are well balanced. Loams have the best properties for cultivation of plants.

Loess Material transported and deposited by wind and consisting of predominantly silt-sized particles. Loess has an open structure and relatively high cohesion due to cementation of clay or calcareous material at grain contacts. A characteristic of loess deposits is that they can stand with nearly vertical slopes.

Losing Stream A stream that loses water as it flows downstream. The water infiltrates into the ground recharging the groundwater.

M

Maximum Allowable Slope means the steepest incline of an excavation face that is acceptable for the most favorable site conditions as protection against cave-ins, and is expressed as the ratio of horizontal distance to vertical rise (H:V).

Mid-America Association of Conservation Districts, or MAACD A regional association of conservation districts serving the urban conservation needs of 10 Kansas and Missouri counties in the Kansas City metropolitan area.

Manning's Equation An equation for determining the flow rate of water in a uniform, steady state condition.

Mass The quantity of matter in a body.

Mass Per Unit Area The amount of material per unit area. Units can be ounces per square yard or grams per square meter.

Mean The average value of a group of numbers.

Mil Abbreviation for one-thousandth.

Mineral Soil (Inorganic Soil) A soil with less than 20 percent organic matter.

Mitigation The process of reducing the negative impacts of a project.

Moisture Content The percentage by weight of water contained in the pore space of a solid material with respect to the total weight of the solid material.

Monomer A relatively simple compound that can react to form a polymer.

Mulch A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, reduces erosion and aids in the establishment of plant cover.

N

Natural Erosion The natural influence of climatic forces on the surface of the earth.

National Pollution Discharge Elimination System, or NPDES Federal legislation that

requires cities with populations over 10,000 to establish a permit process to control sediment pollution. A permit is also required for development sites one acre or greater in size. Permits are authorized and enforced by the Environmental Protection Agency or a designated state agency as directed by the Clean Water Act.

Natural Resources Conservation Service, or NRCS A federal agency, formally known as the Soil Conservation Service, SCS, that provides technical assistance on natural resource management issues. See the Resource Inventory List for more information.

Nonpoint Source Pollution, or NPS Pollution that enters a waterbody from diffuse sources. A point source, by contrast, can be easily identified as having a distinct entry point, such as an industrial or sanitary sewer pipe.

Normal Water Level The average summer water level. The free surface associated with flow in natural streams.

O

Observation Well A vertical pipe placed in the ground to observe groundwater levels.

Open Channel A drainage course that has no restrictive top. It is open to the atmosphere and may or may not permit surface flow to pass over its edge and into another channel in an unrestricted manner. In many cases where dikes are constructed to increase channel capacity, entrance of surface waters is necessarily controlled.

Ordinance A law set forth by a governmental authority.

Organic Matter (Humus) The portion of soil, usually dark in color, resulting from the decomposition of plant and animal materials.

Outfall The location where storm water discharges from a drainageway or conduit to a receiving stream or body of water.

Outlet The point of water discharge from a stream, river, lake or artificial drain.

Outlet Channel A waterway constructed or altered primarily to carry water from structures such as smaller channels, tile lines, dams and diversions.

Overburden (1) The loose soil, sand, silt or clay that overlies bedrock. (2) All material overlying an underground excavation.

Overfall A sudden drop in grade, usually associated with a gully.

Overlap The section of adjacent geosynthetic materials that are in contact, one under the other, forming a seamed or unseamed joint.

P

Pure Live Seed, or PLS A measure of seed quality expressed as a percentage. The product of the percentage of seed purity and the percentage of germination (including the germination of

hard seed) divided by 100.

Particle Size The effective diameter of a particle measured by sedimentation, sieving or micrometric methods.

Peak Discharge The maximum instantaneous flow from a given storm condition at a specific location.

Percent Open Area The net area of a fabric not occupied by fabric filaments, normally determinable only for geotextiles having distinct visible and measurable openings that continue directly through the fabric.

Percolation The downward sub-surface movement of water through the soil horizons. The percolation rate of soil is usually expressed as inches per hour.

Permanent Seeding The establishment of perennial vegetation on disturbed areas for periods longer than 12 months.

Permeability (Soil) The property of the soil that expresses the ease with which water moves downward through the profile. The rate (inches per hour) at which a saturated soil transmits water.

Permittivity The rate of flow of water through a geotextile.

Pervious A property of a material through which water passes relatively freely (e.g., sands and gravels).

pH A measure of the acidity or alkalinity of a substance. A pH value of 7.0 is neutral, less than 7.0 is acidic, greater than 7.0 is alkaline.

Photo degradable The ability of a material to breakdown due to exposure to sunlight.

Pipe A culvert having a non-rectangular cross-section, often assumed to be circular unless specified otherwise, which carries a liquid or gas.

Piping (Tunneling) The movement of soil particles by seepage leading to the development of subsurface voids, tunnels or pipe like cavities.

Plastic A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state and, at some stage in its manufacture or processing into finished particles, can be shaped by flow.

Plasticity The capacity of a soil or rock to be deformed continuously and permanently by relatively moderate pressure without cracking or appreciable volume change.

Polymer A macromolecular material formed by the chemical combination of monomers. Plastics, rubbers and textile fibers are all high molecular weight polymers. Only synthetic polymers are used to make synthetics.

Polyvinylchloride, or PVC A synthetic thermoplastic polymer prepared from vinyl chloride. PVC can be compounded into rigid forms used in pipes or into flexible forms used in the manufacture of geotextiles.

Ponding Water backed up in a channel, depression or ditch as the result of a constriction,

obstruction or lack of outlet.

Porosity The percentage by volume of voids of a given material with respect to the total volume of the material.

Porous Pavement A permeable surface material provides support for traffic without deformation and allows for storm water and surface runoff to gradually infiltrate into the subsoil.

Potable Water Water suitable for human consumption.

Precipitation Process by which water in liquid or solid state (rain, sleet, snow) is discharged out of the atmosphere upon a land or water surface.

Q

Qualified Design Professional Someone trained and highly qualified in their field such as horticulturists, landscapers, various design specialists and technicians.

Qualified Personnel A person knowledgeable in the principles and practice of erosion and sediment controls who possesses the skills to assess conditions at the construction site that could impact storm water quality and to assess the effectiveness of any sediment and erosion control measures selected to control the quality of storm water discharges from the construction activity.

R

Revised Universal Soil Loss Equation, or RUSLE An updated, computerized method of estimating soil movement due to water erosion. RUSLE incorporates the updated climate, soil erodibility and vegetative cover factors of the Universal Soil Loss Equation.

Registered Design Professional A qualified design professional who is normally certified or degreed as an engineer, landscape architect, arborist, forester, biologist, erosion and sediment control specialist, etc.

Reinforcement To strengthen by the addition of materials or support. (e.g., the strengthening of a slope by inclusion of geosynthetic structural materials).

Residual Soil Soil derived by in place weathering of parent material.

Retaining Wall A constructed wall used to eliminate steep slopes while providing stability.

Revetment A lining of stone, concrete, geosynthetics or organic materials used to stabilize a streambank, riverbank or channel.

Rill Erosion See Erosion.

Riparian Area Land adjacent to a body of water at least periodically influenced by concentrated water flows or by flooding.

Riprap Dense stone of various sizes, resistant to weathering, placed on earth surfaces such as the face of a dam or the bank of a stream to prevent scour erosion.

Riser A vertical pipe connected to an underground pipe used to control the discharge rate from a pond or basin.

Rock Natural, solid, mineral matter occurring in large masses or fragments.

Rock Check Structures See Check Dam.

Roll Goods A general term applied to manufactured materials such as erosion control blankets, turf reinforcement mats, netting, geotextiles and other geosynthetics that are furnished in rolls.

Roughness Coefficient A factor in flow formulas representing the effect of channel or conduit roughness on the velocity of flowing water.

Runoff That portion of precipitation not absorbed or retained on the land surface, but which collects and flows from a drainage area. Water that is lost without entering the soil is called surface runoff. Water that enters the soil before reaching a stream channel is called groundwater run off. The rate of surface water runoff in open channels or in storm water conveyance systems is measured in cubic feet per second.

S

Sand (1) Mineral particles that range in size from 2 millimeters to .05 millimeters in equivalent diameter. (2) A loose, granular material that results from the disintegration of rocks, consisting of particles smaller than gravel but coarser than silt. (3) A soil containing 85 percent or more of sand and 10 percent or less of clay.

Sand Diaphragm A vertical wall of sand around a pipe placed through an embankment. Used instead of anti-seep collars. Drainage from the wall is released from the pipe at the downstream toe of the embankment.

Saltation See Erosion.

Saturation (Soil) The point at which all the voids between soil particles are filled with water.

Scarify (1) Roughening the land surface. (2) To abrade the seed coat to improve seed germination.

Scour The clearing and digging action of flowing water, especially the erosion caused by stream water in sweeping away sediment from the streambed and outside bank of a curved channel.

Sediment Mineral or organic material transported from its original location by wind, water, gravity or ice. The word silt is sometimes used interchangeably with the word sediment. This is incorrect. See Silt.

Sedimentation The deposition of soil particles that were transported from its original location by water, wind, ice or gravity.

Seed Bed Soil prepared to promote the germination of seed and the growth of seedlings.

Seed Purity The percentage of the desired species, in relation to the total quantity of bulk material that may include other species, weed seeds or inert matter such as leaves, stems, soil, etc.

Seepage The slow, gravitationally driven, movement of water out of soil, rock, embankments or

structures onto the land surface.

Separation The function of a geotextile or other product as a partition between two adjacent dissimilar materials to prevent mixing of the two materials.

Shear Stress (Tangential Stress) The stress component tangential to a given plane. Basic formula to determine the shear stress of a channel (unit wt. of water [62.4 lbs/ft3] X Slope [ft./ft.] X Depth [ft.] = Shear Stress [lbs/ ft2]).

Sheet Erosion See Erosion.

Sheet Flow Water flowing across a wide, uniform area such as a highway, parking lot or field.

Shoreline Erosion See Erosion.

Shotcrete Mortar or concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. Used to stabilize the surface. Can be applied by a wet or dry mix method.

Shrink-Swell The volume change of soil based on moisture capacity. Soils that shrink when dry and swell when wet can damage plant roots, roads, dams and building foundations.

Silt (1) Mineral particles that range in size from .005 millimeters to .002 millimeters in equivalent diameter. (2) A soil containing 80 percent or more of silt and less than 12 percent clay.
(3) Imprecise colloquial term for a deposition of sediment.

Silt Fence A temporary barrier consisting of a geotextile that is attached to supporting posts and trenched into the ground at the base. As the runoff water slowly filters through the geotextile, the sediment settles out on the uphill side of the silt fence.

Sink Hole A depression in the substrate, usually deep in comparison to its diameter, caused by settlement or substrate particle removal by migrating water.

Site Synonymous with job site.

Slag Rough, cindery material from volcanic lava or smelting operations.

Slide Rapid movement of a part of the earth under force of gravity, usually due to saturated conditions, or an earthquake.

Slope Degree of deviation from horizontal expressed as a percentage, as a numerical ratio or in degrees. As a percentage, slope is the number of feet of rise or fall in 100 feet of horizontal distance. As a ratio, it is the number of feet of horizontal to the number of feet vertical. For example, a 25 percent slope is equal to a 4:1 slope and is equal to a slope of approximately 14 degrees.

Sloughing The separation and downhill movement of a small portion of the slope from surrounding material.

Slump A slope failure in which a mass of rock or unconsolidated material drops along a concave slip surface. Slump material moves downslope as an intact block and frequently rotates backwards.

Slurry A watery mixture of suspended matter.

Small Storm The volume and rate of runoff for rainfall events less than two inches. These small storms [often referred to as the water quality storm] are believed to cause the majority of

urban stormwater pollution.

Soil (Earth) Sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks or organic materials.

Soil Mechanics The application of the laws and principles of mechanics and hydraulics to engineering problems dealing with soil as an engineering material.

Soil Profile Vertical section of the soil from the surface through all horizons.

Soil Stabilization Chemical or mechanical treatment designed to increase or maintain the stability of a mass of soil or otherwise to improve its engineering properties.

Soil Test The process to determine the soil pH and the nutrient-supplying capability of a specific soil for a specific crop or plant species. Used to determine recommended liming and fertilization rates. Available through University Extension offices and private laboratories.

Soil and Water Conservation Society, or SWCS A multidisciplinary membership organization advocating the protection, enhancement and wise use of soil, water and related natural resources located at 945 SW Ankeny Rd., Ankeny, Iowa 50023 or phone 515-289-2331.

Species The basic biological classification of organisms. For example, species of grass include tall fescue, smooth bromegrass and timothy.

Specific Gravity The ratio of the density of a material to the density of water when both densities are obtained by weighing in air. A specific gravity less than one implies that the material will float.

Spillway (Principal) An open or closed channel or conduit used to convey excess water from a pond, reservoir or basin.

Spillway (Emergency) A designed depression at one side of the embankment of a pond or basin that will pass peak discharges greater than the maximum design storm controlled by the principal spillway and detention storage.

Splash Erosion See Erosion.

Splash Pad A nonporous material placed at the outfall of a conduit, channel or grade stabilization structure to decrease energy of water flow to a non-erosive velocity.

Spoil Excess rock or soil material not needed after a practice is constructed.

Sprig A portion of the stem/or roots of a plant used for propagation (e.g., Bermuda grass is commonly established with sprigs rather than seed).

Stable (1) A non-erosive condition in which storm water runoff from a design storm will not cause erosion of soil; usually achieved by protecting erodible areas with structures or vegetation. (2) A soil condition that will not slide or slump; usually established by removing saturated conditions or by flattening slopes.

Stable Outlet A natural or constructed outlet that will dispose of water at non-erosive velocities and without flooding.

Stage The height of the surface of a river above an arbitrary zero point that defines a critical condition. Examples include low flow stage, bank full stage, monitoring stage and flood stage.

Staple A fastening device typically manufactured of 8- to 11-gauge wire, “U” shaped with 4 to 10 inch legs and a 1 to 2 inch crown, used to secure erosion control blankets, geotextiles and related materials to the ground.

Steady Flow A flow in which the volume passing a given point per unit of time remains constant.

Storage Basin Space for detention or retention of storm water runoff water for controlled release during or following the design storm. Storage may be upstream, downstream, offstream, onstream or underground.

Stone Crushed or naturally angular particles of rock between the size of 4.75 and 75 millimeters.

Storm Sewer A conduit that carries storm water, surface drainage, street wash and other washwaters but usually excludes sewage and industrial wastes. Also called a storm drain.

Storm water Water that originates during precipitation events. It may also be used to apply to water that originates from snowmelt.

Storm water Management A master plan or systems approach to the planning of facilities, programs and management organizations for comprehensive control and use of storm water within a defined geographical area.

Stream Hydraulics The science and technology of water behavior in streams.

Structure (1) The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking: some types are crumb, block, platy and columnar. (2) A constructed practice designed to control erosion, sedimentation, storm water runoff or an overfall.

Subgrade The soil prepared and compacted to support a structure or a pavement system.

Subsoil (1) Soil below a sub grade or fill. (2) That part of the soil profile occurring below the “A” horizon.

Subsurface Drain (Underdrain) A perforated pipe used for subsurface drainage, usually surrounded by aggregate or wrapped in a geotextile filter fabric to prevent the migration of soil particles.

Suspension The state of a substance when its particles are kept from falling or sinking. See Erosion.

Swale A low-lying, often wet, area of land.

Synthetic Any material created by artificial means.

T

Tackifier See Binder.

Tangential Stress See Shear Stress.

Temporary Seeding The establishment of fast-growing annual vegetation to provide economical erosion control for up to 12 months and to reduce the amount of sediment moving

off the site.

Tensile Strength The maximum force a material can bear without tearing apart. Units are reported as maximum stress (e.g., pounds per square inch) or force per unit thickness (e.g., pounds per inch width).

Tenting Separation of installed manufactured blankets from contact with the ground surface. This is usually due to clods of soil not fine graded and prepared properly for blanket installation.

Texture The percent of sand, silt and clay in a soil.

Tillage The mechanical manipulation of soil with equipment such as plows, discs, cultivators or harrows. Also, tilled land.

Toe Drain A subdrain installed near the downstream toe of a dam or levee to intercept seepage and to outlet it away from the structure.

Toe of Slope The junction of a slope and the bottom of the slope.

Top of Slope The junction of a slope and the top of the berm, channel or embankment.

Topographic Map A map of isolines linking common elevations that effectively illustrates the contours of the land surface.

Topsoil Surface soil usually containing organic matter. The fertile soil most capable of growing vegetation and crops.

Toxic The characteristic of being poisonous or harmful to plant or animal life.

Trash Rack A structural device used to prevent debris from entering a pipe, spill way or other water structure.

Turbidity The degree of cloudiness in water caused by suspended particles. Turbidity can be precisely measured in nephelometric turbidity units (ntu) and is often used as an indicator of pollution.

Turf Reinforcement Mat, or TRM Permanent synthetic erosion control blankets that can reduce the loss of underlying soil and reinforce the root zone of vegetation. TRM can be used to improve the ability of vegetation to resist heavier, more erosive, flows that would otherwise compromise the integrity of the plant materials.

U

Underdrain See Subsurface Drain.

Undermining A process of scour by hydraulic action that progressively removes earth support from a structure. Undermining commonly occurs at the outlet of a culvert or sewer.

Ultraviolet Degradation Breakdown of polymeric structures when exposed to the ultraviolet bandwidth of light.

Ultraviolet Radiation Stability, or UV The ability of a material to resist deterioration from exposure to the ultraviolet component of sunlight.

Uniform Flow Flow in which the velocities are the same in both magnitude and direction from point to point along the stream or conduit.

Unsheltered Distance The distance from the downwind edge of an area and a stable point in the direction of the prevailing wind. Used as a factor in estimating wind erosion.

Unsteady Flow A flow in which the velocity changes with respect to both space and time.

Upland The region of higher elevations above a floodplain.

Uplift The hydrostatic force of water exerted on or underneath a structure, causing a displacement of the structure.

Universal Soil Loss Equation, or USLE An estimate of the amount of soil that moves due to water erosion based upon five factors: climate, soil erodibility, length and steepness of slope, vegetative cover and structural or management practices.

V

Vegetation Plant life or total plant cover of an area.

Void (1) Space in a soil or rock mass not occupied by solid mineral matter. This space is generally occupied by air or water. (2) The open spaces in a geosynthetic material through which flow can occur.

W

Washout The failure of a culvert, bridge, embankment or other structure resulting from the action of flowing water.

Water Course A natural or artificial channel in which a flow of water occurs, either continuously or intermittently. Water courses may be either on the surface or underground.

Water Quality The chemical, physical and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water Quality Storm The volume and rate of runoff for rainfall events less than 2 inches. These small storms are believed to cause the majority of urban storm water pollution.

Water Table (Ground Water Level) The upper surface of the zone of saturation in permeable rock or soil.

Watershed The region drained by or contributing water to a stream, lake or other body of water.

Wattle See Fascine.

Weathering The process of disintegration and decomposition as a consequence of exposure to the atmosphere, to chemical action and to the action of frost, water and heat.

Weir A structure that extends across the width of a channel and is intended to delay or alter the flow of water through the channel.

Well Graded An equal distribution of particle sizes. Usually refers to gravel.

Wetland Land area that is wet or flooded by surface or groundwater often enough and long enough to develop characteristic hydric soil properties and to support vegetation that will grow in saturated soil conditions.

Wetted Perimeter The length of wetted contact between a stream of water and its containing channel measured at right angles to the direction of flow.

Wind Erosion Equation An estimate of the amount of soil that moves due to wind erosion based upon five factors: soil erodibility, ridge roughness, climate, unsheltered distance and vegetative cover.

APPENDIX C
REFERENCES

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APPENDIX D
REFERENCES

Environmental Protection Agency Web Publication Resources

Appendix A: SWPPP Template epa.gov/npdes/pubs/sw_swppp_template.doc

Appendix B: Sample Inspection Report Instructions
epa.gov/npdes/pubs/sw_swppp_inspection_form.doc

EPA Regional Environmental Information and Map water.epa.gov/type/location/regions

Low Impact Development (LID) www.epa.gov/owow/NPS/lid

Managing Wet Weather with Green Infrastructure
cfpub.epa.gov/npdes/home.cfm?program_id=298

National Menu of Stormwater Best Management Practices
cfpub.epa.gov/npdes/stormwater/menuofbmps

Outreach Material and Reference Documents cfpub.epa.gov/npdes/stormwatermonth.cfm

Stormwater Pollution Prevention Plans for Construction Activities
cfpub.epa.gov/npdes/stormwater/swppp.cfm

Stormwater Discharges from Industrial Facilities cfpub.epa.gov/npdes/stormwater/indust.cfm

Stormwater Regional Contacts cfpub.epa.gov/npdes/contacts.cfm?program_id=6&type=REGION

Stormwater State Contacts cfpub.epa.gov/npdes/contacts.cfm?program_id=6&type=STATE

Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s)
cfpub.epa.gov/npdes/stormwater/munic.cfm

Urban BMP Performance Tool
cfpub.epa.gov/npdes/stormwater/urbanbmp/bmpeffectiveness.cfm

Professional Organizations and Other National Resources

American Public Works Association – www.apwa.net

Construction Industry Compliance Assistance Center - www.cicacenter.org

EnviroCert International - www.envirocertintl.org

Nonpoint Education for Municipal Officials - nemo.uconn.edu

The International Stormwater BMP Database - www.bmpdatabase.org

Center for Watershed Protection www.cwp.org

Missouri Chapter of the Land Improvement Contractors Association, 7016 East North Shore Drive, Hartsburg, MO 65039-9631 Phone (573) 634-3001 Fax 573 761-0375
Email: mlica@aol.com, Webpage www.mlica.org

Stormwater Manager's Resource Center www.stormwatercenter.net

Street Edge Alternatives www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/GreenStormwaterInfrastructure/NaturalDrainageProjects/StreetEdgeAlternatives/

The Soil and Water Conservation Society. 945 SW Ankeny Road, Ankeny, IA 50021
Phone: 515-289-2331 Fax: 515-289-1227 www.swcs.org

The International Erosion Control Association, 3401 Quebec St, Suite 3500, Denver, CO 80207 USA. Phone 800-455-4322 (+ 1 303-640-7554 International). Fax 866-308-3087 www.ieca.org

The Certified Inspector of Sediment and Erosion Control (CISEC) ProgramCISEC, Inc. - www.cisecinc.org/

State Resources

The Missouri Department of Natural Resources, Division of Environmental Quality, Water Pollution Control Program handles permits for land disturbance. Write Missouri Department of Natural Resources, P.O. Box 176, 205 Jefferson St., Jefferson City, MO 65102 or call 573-751-1300 or visit the Missouri Stormwater Information Clearinghouse at www.dnr.mo.gov/env/wpp/stormwater

The Missouri Department of Natural Resources has regional offices in:

Kansas City	816-622-7000
Macon	660-385-8000
St. Louis	314-416-2960
Springfield	417-891-4300
Poplar Bluff	573-840-9750

More information on these offices and additional satellite offices can be located at www.dnr.mo.gov/regions/regions.htm

The Missouri Department of Conservation, or MDC, has experts on staff that can provide lists of plant materials suitable for wetlands and streambanks; they also have experience and recommendations on bioengineering techniques for streambank stabilization. Contact your local MDC office listed in the state government section of the phone book, call their central office at 573-751-4115 or visit the Missouri Department of Conservation website at mdc.mo.gov/regions.

Missouri Grow Native! is a joint project between the Missouri Department of Conservation and Missouri Department of Agriculture offers the following website of photographs and narrative descriptions of Missouri native plants: www.grownative.org/

Missouri Stream Team Program is a joint project between the Missouri Department of Natural Resources and the Missouri Department of Conservation. Missouri Stream Team is a working partnership of citizens who are concerned about Missouri Streams. Call 800-781-1989, write Missouri Department of Conservation Stream Team Unit at PO Box 180., Jefferson City, MO 65102-0180, email STREAMTEAM@mdc.mo.gov or visit www.mostreamteam.org

University of Missouri Extension Service has local offices in almost every county. The offices have on-staff experts in agronomy, engineering and other disciplines. Extension staff can provide the latest in research results and may be particularly helpful in vegetation establishment. A variety of guides can be picked up at these offices. Soil samples can be turned in at the offices for soil testing. Call 573-882-7216 or visit extension.missouri.edu.

Watershed Committee of the Ozarks mission is to preserve and improve the water supplies of Springfield and Greene County through education and effective management of the region's watersheds. Write 320 North Main Avenue, Springfield, MO 65806-1208, call 417-866-1127 or visit www.watershedcommittee.org.

Kansas State Conservation Commission for information provides information on streambank stabilization. Write KSCC, 109 SW Ninth Suite 500, Mills Bldg., Topeka, KS 66612-1299, call 785-296-3600, fax 785-296-6172, email SCCOA@scc.ks.gov or visit www.scc.ks.gov.

Kansas Department of Wildlife and Parks provides information on bioengineering, plant materials, native seedings and stream monitoring and assessment. Write KDWP, Kansas Department of Wildlife & Parks Operations Office Environmental Services Section, 512 SE 25th Ave., Pratt, KS 67124, call (620) 672-5911, fax 620-672-2972 or visit www.kdwp.state.ks.us/news/Other-Services/Stream-Assessment-and-Monitoring-Program

The Kansas Department of Health and Environment handles permits for land disturbance. Write KDHE, Bureau of Water, Building 283, Forbes Field, Topeka, KS 66620 or call 785-296-5557. More information on KDHE resources can be located at www.kdheks.gov/stormwater.

Local Resources

Contact the authorizing unit of local government (city or county) for local regulations and permit requirements. These will usually be listed in the appropriate government section (city or county) of the phone book under Government Engineer, Government Building, etc.

County Soil & Water Conservation Districts and local university extension offices can provide information on plant materials, erosion and sediment control, and most offices have a Soil Survey of the county. Check your local phone directory.

APPENDIX E
GUIDE TO THE METRIC SYSTEM

Length		
Unit	**Number of Square Meters**	**Approximate U.S. Equivalent**
Myriameter	10,000	6.214 miles
Kilometer	1,000	0.621 mile
Hectometer	100	109.361 yards
Decameter	10	32.808 feet
Meter	1	39.370 inches
Decimeter	0.1	3.937 inches
Centimeter	0.01	0.394 inch
Millimeter	0.001	0.039 inch

Area		
Unit	**Number of Square Meters**	**Approximate U.S. Equivalent**
Square kilometer	1,000,000	0.386 square mile
Hectare	10,000	2.477 acres
Are	100	119.599 square yards
Deciare	10	11.960 square yards
Centare	1	10. 764 square feet
Square centimeter	0.0001	0.155 square inch

Volume		
Unit	**Number of Square Meters**	**Approximate U.S. Equivalent**
Decastere	10	13.079 cubic yards
Stere	1	1.308 cubic yards
Decistere	0.01	3.532 cubic feet
Cubic Centimeter	0.000001	0.061 cubic feet

Metric Conversion Chart - Approximations		
When You Know	**Multiply By**	**To Find**
Length		
Millimeters	0.0	inches
Centimeters	40.39	inches
Meters	3.28	feet
Meters	1.09	yards
Kilometers	0.62	miles
Inches	25.40	millimeters
Inches	2.54	centimeters
Feet	30.48	centimeters
Yards	0.91	meters
Miles	1.61	kilometers
Area		
Square Centimeters	0.16	square inches
Square Meters	1.20	square yards
Square Kilometers	0.39	square miles
Squares(10,000m2)	2.47	acres
Square Inches	6.45	sq. centimeters
Square Feet	0.009	square meters
Square Yards	0.84	square meters
Square Miles	2.60	sq. kilometers
Acres	0.40	hectares
Mass and Weight		
Grams	0.035	Ounce
Kilograms	2.21	Pounds
Tons	1.10	Short Tons
Ounces	28.35	Grams
Pounds	0.45	Kilograms
Short Tons (2000lb)	0.91	Tons

Metric Conversion Chart - Approximations		
When You Know	**Multiply By**	**To Find**
Volume		
Milliliters	0.20	Teaspoons
Milliliters	0.06	Tablespoons
Milliliters	0.03	Fluid Ounces
Liters	4.23	Cups
Liters	2.12	Pints
Liters	1.06	Quarts
Liters	0.26	Gallons
Cubic Meters	35.32	Cubic Feet
Cubic Meters	1.35	Cubic Yards
Teaspoons	4.93	Milliliters
Tablespoons	14.78	Milliliters
Fluid Ounces	29.57	Milliliters
Cups	0.24	Liters
Pints	0.47	Liters
Quarts	0.95	Liters
Gallons	3.79	Liters
Cubic Feet	0.03	Cubic Meters
Cubic Yards	0.76	Cubic Meters
Speed		
Miles/Hour	1.61	Kilometers/Hour
Kilometers/Hour	0.62	Miles/Hour
Temperature		
Celsius temp.	9/5. +32	Fahrenheit temp.
(exact) Fahrenheit temp.	-32. 5/9 x remainder	Celsius temp.

Temperatures in degrees Celsius, as in the familiar Fahrenheit system, can only be learned through experience. The following temperatures are ones that are frequently encountered:

0°C	Freezing point of water (32°F)
10°C	A warm winter day (50°F)
20°C	A mild spring day (68°F)
30°C	A hot summer day (86°F)
37°C	Normal body temperature (98.6°)
40°C	Heat wave conditions (104°F)
100°C	Boiling point of water (212°F)

APPENDIX F
ACRONYMS

AST Above ground storage tanks

BMP Best Management Practices

CWA Clean Water Act

ECC Effective Calcium Carbonate

ENM Equivalent Neutralizing Material

EPA Environmental Protection Agency

FEMA Federal Emergency Management Agency

HDPE High-Density Polyethylene

KDHE Kansas Department of Health and the Environment

LEED Leadership in Energy and Environmental Design

LEPC Local Emergency Planning Committee

LID Low Impact Development

MDC Missouri Department of Conservation

MDNR Missouri Department of Natural Resources

MoDOT Missouri Department of Transportation

MS4 Municipal Separate Storm Sewer System

MSDS Material Safety Data Sheets

NPDES National Pollutant Discharge Elimination System

NRCS Natural Resources Conservation Service

NTU Nephelometric Turbidity Units

O&M Operations and Maintenance

OHWM Ordinary High Water Mark

OSHA Occupational Safety and Health Administration

PAM Polyacrylamide

PVC Polyvinyl Chloride

SCM: Stormwater Control Measure

SWPPP: Stormwater Pollution Prevention Plan

TMDL: Total Maximum Daily Load

UST Underground Storage Tank

WCC Water Clarifying Compounds

United States Environmental Protection Agency | Solid Waste and Emergency Response (5306W) | EPA530-F-97-043 October 1997 www.epa.gov

Innovative Uses of Compost Erosion Control, Turf Remediation, and Landscaping

Compost has been viewed as a valuable soil amendment for centuries. Most people are aware that the use of compost is an effective way to improve plant growth. Compost-enriched soil can also reduce erosion, alleviate soil compaction, and help control disease and pest infestation in plants. These beneficial uses of compost can increase healthy plant production, help save money, reduce the use of chemical fertilizers, and conserve natural resources.

Compost used for a specific purpose or with a particular soil type works best when it is tailor-made or specially designed. For example, compost that is intended to prevent erosion might not provide the best results when used to alleviate soil compaction, and vice versa. Technical parameters to consider when customizing a compost mixture include maturity, stability, pH level, density, particle size, moisture, salinity, and organic content, all of which can be adjusted to fit a specific application and soil type.

Compost Technology to Control Erosion

According to the U.S. Department of Agriculture, the United States loses more than 2 billion tons of topsoil through erosion each year. Erosion occurs when wind and rain dislodge topsoil from fields and hillsides. Stripped of its valuable top layer, which contains many essential nutrients, the soil left behind is often too poor to sustain good plant growth. Eroded topsoil can also be carried into rivers, streams, and lakes. This excess sediment, sometimes containing fertilizers or toxic materials, threatens the health of aquatic organisms. It can also compromise the commercial, recreational, and aesthetic value of water resources. As a result, preventing erosion is essential for protecting waterways and maintaining the quality and productivity of soil.

Controlling Erosion in Construction and Road Building

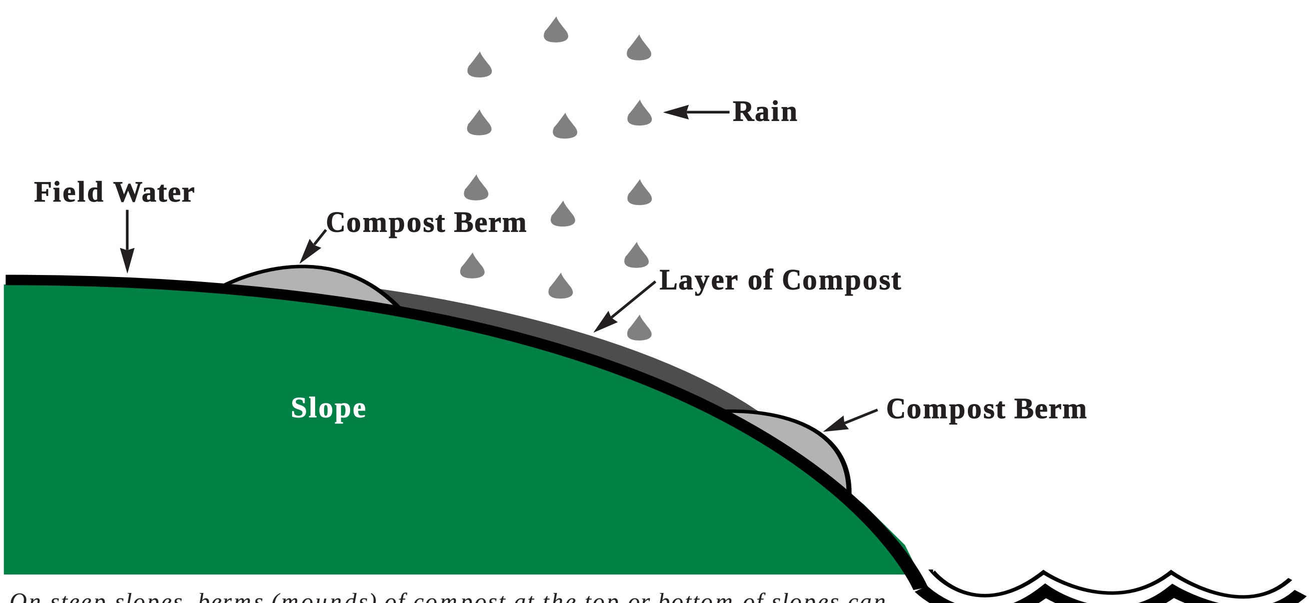
Erosion is a naturally occurring process; however, it is often aggravated by activities such as road building and new construction. At the beginning of some construction projects, all vegetation and topsoil is removed, leaving the subsoil vulnerable to the forces of erosion. On steep embankments along roads and highways, compost can be more effective than traditional hydromulch at reducing erosion and establishing turf because compost forms a thicker, more permanent growth due to its ability to improve the infrastructure of the soil.

Depending on the length and height of a particular slope, a 2- to 3-inch layer of mature compost, screened to 1/2 to 3/4 of an inch and placed directly on top of the soil, has been shown to control erosion by enhancing planted or volunteer vegetation growth. On steep slopes, berms (mounds) of compost at the top or bottom of slopes can be used to slow the velocity of water and provide additional protection for receiving waters. Because of its ability to retain moisture, compost also helps protect soil from wind erosion and during droughts.

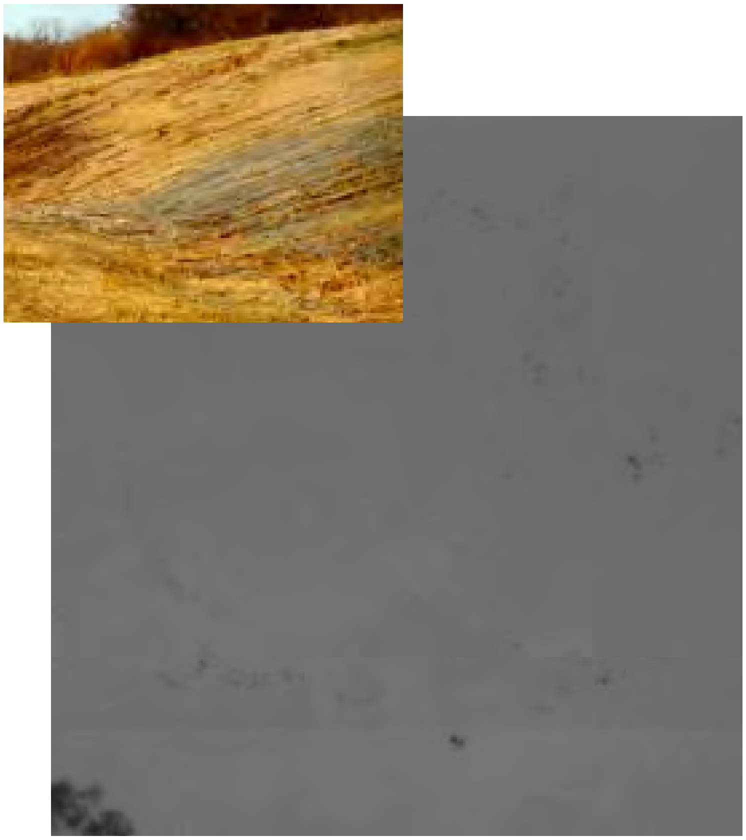
Controlling Erosion in Road Construction

The Federal Highway Administration (FHWA), of the U.S. Department of Transportation and the U.S. Environmental Protection Agency, recently conducted an erosion control demonstration project that compared mature yard trimmings compost that met FHWA specifications with hydromulch, a substance traditionally used for controlling erosion on roadside embankments. The purpose of the study was to determine the effectiveness of mature yard trimmings compost compared with hydromulch in establishing Fescue grass.

The project site was at a newly constructed intersection in suburban Washington, DC. Two embankments with steep slopes were selected. The first embankment had a 2 to 1 slope; the second had a 3 to 1 slope. A hydromulch/fertilizer treatment also was applied to a section of each of the slopes. Adjacent to these sections, 2-1/2 inches of mature yard trimmings compost was spread. On the 2 to 1 slope, a small amount of fertilizer was also applied, while the 3 to 1 slope was left unfertilized. Fescue grass seed was added and covered with a thin layer of compost to conceal the seed from birds.



On steep slopes, berms (mounds) of compost at the top or bottom of slopes can be used to slow the velocity of water and provide additional protection for receiving waters.



Photos courtesy of The Federal Highway Administration, Office of Environment & Planning, and Federal Lands Highway Program

Embankment adjacent to new intersection. Top left photo shows hillside before seeding. Photo at right shows grass cover. Compost-treated plot displays darker green color and thicker growth.

Results of the project revealed that compost used alone produced better results than either of the areas treated with hydromulch or the area treated with compost and fertilizer. While the areas with the hydromulch/fertilizer combination showed quick initial vegetative growth, the areas treated with only compost persevered within 6 months, out-performing the traditional method by establishing a thick, healthy vegetative cover. The growth in the compost/fertilizer plot was superior to that found in the hydromulch/fertilizer plots. A possible explanation for compost alone out-performing the area treated with compost and fertilizer is that chemical fertilizers often increase soil salinity, which in turn could negatively affect the beneficial micro-organisms in compost and inhibit the establishment of healthy grasses.

Using Compost to Remediate Turf Grasses

Providing safe, uniform playing surfaces for recreational activities, such as golf, football, soccer, and other field sports, requires intensive turf management. Recreational turf grasses are subjected to extensive wear and tear, making them difficult to manage and highly susceptible to turf diseases, pests, and soil compaction. To address these problems, turf managers traditionally use a combination of fertilizers, pesticides, fungicides, and aeration techniques that usually result in high costs and potential for negative environmental impacts.

Some turf managers are now using compost to replace peat moss in their topdressing applications based on its proven success in suppressing plant disease. Compost, when properly formulated, unlike peat moss, is teeming with nutrients and micro-organisms that stimulate turf establishment and increase its resistance to common turf diseases, such as snow mold, brown patch, and dollar spot. For example, after 3 years of using compost as a topdressing, the Country Club of Rochester, New York, has nearly eliminated the need for fungicide applications for such diseases.

Alleviating Soil Compaction

Soil compaction is another persistent landscape management problem, particularly in areas of heavy traffic, such as parks, zoos, golf courses, and athletic playing fields. Compacted soil impedes healthy turf establishment by inhibiting the movement of air, water, and nutrients within the soil. Bare soil, weeds, increased runoff, and puddling after heavy rains are the most obvious signs of a soil compaction problem.

Traditional methods for alleviating soil compaction—aeration, reseeding, or complete resodding—are labor-intensive and expensive, and

What Are the Benefits of Using Compost?

Soil Enrichment:

- **Adds organic bulk and humus to regenerate poor soils.**
- **Helps suppress plant diseases and pests.**
- **Increases soil nutrient content and water retention in both clay and sandy soils.**
- **Restores soil structure after reduction of natural soil microbes by chemical fertilizer.**
- **Reduces or eliminates the need for fertilizer.**
- **Combats specific soil, water, and air problems.**

Pollution Remediation:

- **Absorbs odors and degrades volatile organic compounds.**
- **Binds heavy metals and prevents them from migrating to water resources or being absorbed by plants.**
- **Degrades, and in some cases, completely eliminates wood preservatives, petroleum products, pesticides, and both chlorinated and nonchlorinated hydrocarbons in contaminated soils.**

Pollution Prevention:

- **Avoids methane production and leachate formation in landfills by diverting organics for composting.**
- **Prevents pollutants in stormwater runoff from reaching water resources.**
- **Prevents erosion and silting on embankments parallel to creeks, lakes, and rivers.**
- **Prevents erosion and turf loss on roadsides, hillsides, playing fields, and golf courses.**

Economic Benefits:

- **Results in significant cost savings by reducing the need for water, fertilizers, and pesticides.**
- **Produces a marketable commodity and a low-cost alternative to standard landfill cover and artificial soil amendments.**
- **Extends municipal landfill life by diverting organic materials from the waste stream.**
- **Provides a less costly alternative to conventional bioremediation techniques.**

provide only short-term solutions. Some turf managers are starting to use compost and compost amended with bulking agents, such as aged crumb rubber from used tires or wood chips, as cost-effective alternatives. Incorporating tailor-made composts into compacted soils improves root penetration and turf establishment, increases water absorption and drainage, and enhances resistance to pests and disease. Using tailored compost can also significantly reduce the costs associated with turf management. Research conducted at a U.S. Air Force golf course in Colorado Springs, Colorado, for example, indicated that turf grown in areas improved with tailored compost required up to 30 percent less water, fertilizer, and pesticides than turf treated conventionally.

Greening the Links

The U.S. Army Golf Course Operations Division at Fort George Meade, Maryland, and the U.S. Environmental Protection Agency began a 3-year pilot demonstration in 1995 to determine the effectiveness of compost amended with crumb rubber in alleviating soil compaction, erosion, and turf disease problems. The golf course superintendent estimates that using compost technology would save nearly $50,000 a year in maintenance costs.

Photo courtesy of U.S. Army, Fort George Meade, Maryland

At the U.S. Army Golf Course at Fort George Meade, Maryland, erosion can clearly be seen on the untreated right side of the path, while rubber amended compost is helping keep erosion in check on the left.

Mature yard trimmings compost amended with crumb rubber was incorporated into compacted soils at 13 different locations around the two golf courses. Many of the selected sites included areas adjacent to, or at the end of golf cart paths, on slopes surrounding greens, or in tee boxes. These sites were selected because of their susceptibility to compaction and erosion caused by heavy traffic and water runoff. The compost mixture was tilled into the soil to a depth of about 3 to 5 inches and then uniformly seeded. To act as a control, one of the plots was amended only with crumb rubber.

In the first year of the pilot, course operators reported that healthy, green turf grass took hold at most of the sites, with no signs of compaction or erosion. Results were particularly impressive in eroded ditches along cart paths. The areas treated with the compost mixture showed full growth of turf grasses and total abatement of erosion, whereas the plot amended only with crumb rubber showed few signs of improvement.

Using amended compost can significantly reduce the costs associated with turf management.

Using Compost in Landscaping Activities

Supplies of high-quality, low-cost topsoil are declining, particularly in urban areas where the demand is greatest. Compost is, therefore, becoming particularly important in applications requiring large amounts of topsoil. Increasingly, compost is being used as an alternative to natural topsoil in new construction, landscape renovations, and container gardens. Using compost in these types of applications is not only less expensive than purchasing topsoil, but it can often produce better results when trying to establish a healthy vegetative cover.

After a lawn or garden has been established, maintaining it can be a challenge for both home gardeners and commercial landscape contractors. While aeration, topdressing, and chemical fertilizer applications are some of the techniques commonly employed in landscaping applications, compost can be a successful alternative. When used as a topdressing, or periodically tilled into the soil, compost can stimulate plant growth, reduce pests and plant infestation, and improve soil structure.

Compost is also an effective landscaping mulch. Placed over the roots of plants, compost mulch conserves water and stabilizes soil temperatures. In addition, compost mulch keeps plants healthy by controlling weeds, providing a slow release of nutrients, and preventing soil loss through erosion. Landscapers and gardeners also use compost as mulch because its dark, rich color accents the vibrant colors of flowering plants.

Landscaping Constitution Gardens

In 1973, the U.S. National Park Service used a compost mixture made of digested sewage sludge, wood chips, leaf mold, and a small amount of topsoil to transform a badly compacted 40-acre tract of land located in Washington, DC, into a landscaped park. This project is one of the earliest successful large-scale landscaping applications using compost.

The original plans for the park renovations included planting azalea beds and thousands of annuals around a 6-acre lake. However, the site assessment revealed that the soil was almost as hard as concrete, with little pore space for plant roots and for water infiltration. The soil was too low in nutrients for healthy plant growth. In addition, the water table was high, causing flooding and root rot in existing plants.

Park Service staff spread over 9,400 cubic yards of the compost mixture over the site. Fertilizer, woodchips, and seed were added, and the soil was tilled to a depth of 2 feet. Impressed by the hardiness and beauty of a stand of hardwood trees along the area's western edge, Park Service staff decided to plant several varieties of native trees rather than the planned azalea beds. Data taken 3 years after the project ended indicated that most of the nearly 2,000 trees initially planted had flourished in the park.

Photo courtesy of U.S. National Park Service

More than 9,400 cubic yards of compost was used to remediate heavily compacted soil at Constitution Gardens in Washington, DC.

Photo courtesy of U.S. National Park Service

Three years after compost was applied, the vegetation at Constitution Gardens flourishes.

The compost use in this project not only improved the quality of the existing soil, but also saved taxpayers over $200,000. Park Service staff also reviewed other options for remediating the soil at the park, including the purchase of topsoil to spread over the existing poor soil. If the Park Service staff had chosen to use topsoil, the cost of the project would have doubled.

Using Compost for Rooftop Gardens

Several years ago, officials at Pace School in Pittsburgh, Pennsylvania, proposed building a playground and garden for their students. They soon discovered, however, that the only space available was on the school's roof, so they designed a unique rooftop garden.

Plans for the garden included building large, 6-foot deep planters. Before the planters were constructed, several important factors had to be taken into consideration. The planter mix used had to be light enough for the roof to withstand the weight, yet dense enough to prevent rapid evaporation caused by the wind and summer heat. In addition, the planter mix had to be able to endure freezing temperatures in winter, and provide adequate drainage to prevent the planters from overflowing during rainstorms.

Photo courtesy of AgRecycle Inc.

Tailor-made compost was the key to success for the rooftop garden at Pace School in Pittsburgh, Pennsylvania.

To meet these special needs, the school decided to use a tailor-made mature compost blend, chosen because its bulk density is much lighter than soil-based mixes. The compost mix is also extremely absorbent, maintains good drainage, and protects plant roots from climatic fluctuations.

A local compost producer tailor-made a mature yard trimmings compost mixture to meet the project's specifications. A layer of polystyrene packaging peanuts was placed in the bottom of each planter box to enhance drainage, and a 5-foot layer of the compost mixture was placed on top.

Four years after the project began, the school continues to use its rooftop garden for a number of activities, including teaching science classes and gardening methods. The compost has performed very well as a growing medium and continues to produce beautiful, healthy plants that both the students and teachers can enjoy.

Using Compost in Landscape Maintenance

Each year, millions of people visit Point State Park in Pittsburgh, Pennsylvania. Heavy traffic and 12 continuous years of chemical fertilizer applications caused the park's grassy areas to become increasingly compacted, eroded, and depleted of vital nutrients.

After considering several options, park officials decided to aerate the grassy areas and apply a special blend of mature yard trimmings compost and fire calcined clay. This compost mixture was designed to alleviate compaction, add nutrients to the soil, and to improve water-holding capacity. Workers spread a 1/4-inch topdressing of the compost mixture and then uniformly applied grass seed. Soon after the compost was applied, park officials noted that the turf was healthier and that the soil no longer exhibited signs of compaction.

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